ORDER **8260. 51**

UNITED STATES STANDARD

for

Required Navigation Performance (RNP) Instrument Approach Procedure Construction

December 30, 2002

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Distribution: A-W(AS/ND/AT/AF/FS)-3; AVN-100(150CYS); AMA-200 (80 CYS)
A-X(FS/AF/AT/AS)-3; Special Military and Public Addressees

Initiated By: AFS-420

RECORD OF CHANGES

8260.51

CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE	CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

CHAPTER 1. GENERAL

1.0 PURPOSE.

These criteria are the Federal Aviation Administration (FAA) standard for developing instrument approach procedures based on required navigation performance (RNP) using area navigation (RNAV) avionics systems. Criteria are specified for approach procedures based on minimal mandatory equipage enabling the largest possible population of users to realize the benefits of RNP. Additionally, criteria are provided for more sophisticated procedures requiring higher levels of equipage, and associated operational requirements to achieve special authorization for use. This order, a proposed 90-series Advisory Circular (AC), and a proposed 20-series AC will provide the foundation for RNP instrument flight rule (IFR) operations.

1.1 DISTRIBUTION.

This order is distributed in Washington headquarters to the branch level in the Offices of Airport Safety and Standards and Communications, Navigation, and Surveillance Systems; to Air Traffic, Airway Facilities, and Flight Standards Services; to the National Flight Procedures Office and the Regulatory Standards Division at the Mike Monroney Aeronautical Center; to branch level in the regional Flight Standards, Airway Facilities, Air Traffic, and Airports Divisions; special mailing list ZVS-827, and to special military and public addressees.

1.2 EFFECTIVE DATE. March 3, 2003

1.3 BACKGROUND.

The concept of RNP is a significant enhancement to navigable airspace design, use, and management. It was developed by the International Civil Aviation Organization (ICAO) Special Committee on Future Air Navigation Systems (FANS) and is an integral part of the communication, navigation, surveillance, and air traffic management (CNS/ATM) plan envisioned by the Special Committee. RNP levels address obstacle protection associated with RNP accuracy values. The RNP level (RNP x, where x=0.3, 1, 2, etc.), when applied to instrument procedure obstacle evaluation areas, is a variable used to determine a segment primary area half-width value; i.e., total width is ± a multiple of the value used to identify the level.

1.4 GENERAL.

Criteria exploiting mandatory avionics features for RNP certification (such as track-to-fix capability) are considered **BASIC** criteria and are available for application in any RNP approach procedure. Criteria exploiting features that are not mandatory (such as radius-to-fix leg type capability) are considered **ADVANCED** criteria applicable only to approach procedures that require special authorization for use. Minimums based on application of ADVANCED criteria must be published under the " *Special Aircraft and Aircrew*

Authorization Required" format similar in depiction to category II/III approach procedures. Some drawings in this order are not to scale. All possible construction scenarios cannot be anticipated and addressed in this order; therefore, sound judgment and common sense based on procedure development experience is necessary in some construction scenarios.

1.4.1 Formulae Used in RNP Criteria.

Formulae are numbered for easy reference. A complete list of the formulas is located in appendix 1.

1.4.2 Critical Comments.

An explanatory comment is indicated as a numbered footnote (like this example[(3)]) referring the reader to a like numbered comment located in appendix 2.

1.4.3 Risk Assessment/Validation of RNP Obstacle Clearance Surfaces.

This report (appendix 3) will provide supporting material justifying values used for determining obstacle clearance zones for certain RNP operations defined in this Order – including straight, level flight; fly-by turns between two legs of the same RNP; and straight flight through a transition from a higher RNP to a lower one.

1.5 DEFINITIONS.

For the purposes of this document, the following definitions apply:

1.5.1 Approach Surface Baseline (ASBL).[(1)]

A line aligned to the runway centerline (RCL) that lies in a plane parallel to a tangent to the orthometric geoid (WGS-84 ellipsoid for Wide Area Augmentation System/Local Area Augmentation System (WAAS/LAAS)) at the runway threshold. It is used as a baseline reference for vertical measurement of the height of the glidepath and obstruction clearance surfaces (see figure 1-3)

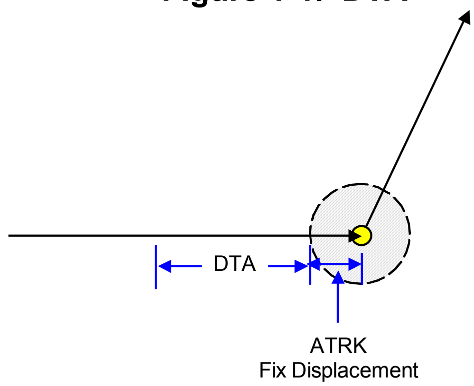
1.5.2 Decision Altitude (DA).

A specified barometric altitude at which a missed approach must be initiated if the required visual references to continue the approach have not been established.

1.5.3 Distance of Turn Anticipation (DTA).

The distance from (prior to) a fly-by fix that an aircraft is expected to start a turn to intercept the course of the next segment (see figure 1-1). Since there is an along-track fix displacement value associated with a fix, this value is added to DTA to assure initiation of the turn will occur in a timely manner.

Figure 1-1. DTA



1.5.4 Final Approach Segment (FAS).

The FAS begins at the final approach fix (FAF) and ends at the landing threshold point (LTP). For obstacle evaluation purposes, the FAS begin at the along-track fix displacement value prior to the FAF and ends at the LTP. The FAS is typically aligned with the runway centerline extended.

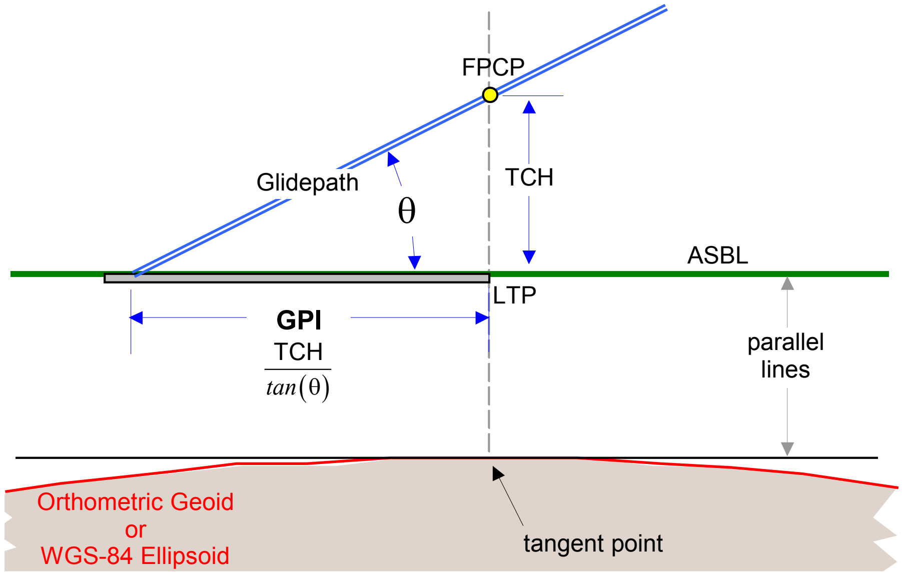
1.5.5 Flight Path Control Point (FPCP).

The FPCP is a 3D point defined by the LTP latitude/longitude position, MSL elevation, and a threshold crossing height (TCH) value. The FPCP is in the vertical plane of the final approach course and is used to relate the glidepath angle of the final approach track to the landing runway. It is sometimes referred to as the TCH point or reference datum point (RDP) (see figure 1-3).

1.5.6 Glidepath Angle (GPA).

The GPA is the angle of the specified final approach descent path relative to the ASBL (see figure 1-2). In this order, the glidepath angle is represented in formulas and figures as the Greek symbol θ.

Figure 1-2. FPCP, GPA, GPI



1.5.7 Ground Point of Intercept (GPI).

The glidepath intercepts the ASBL at the GPI. The GPI is expressed as a distance in feet from the LTP. $\mathbf{GPI} = \frac{\mathbf{TCH}}{tan(\theta)}$ (see figure 1-2).

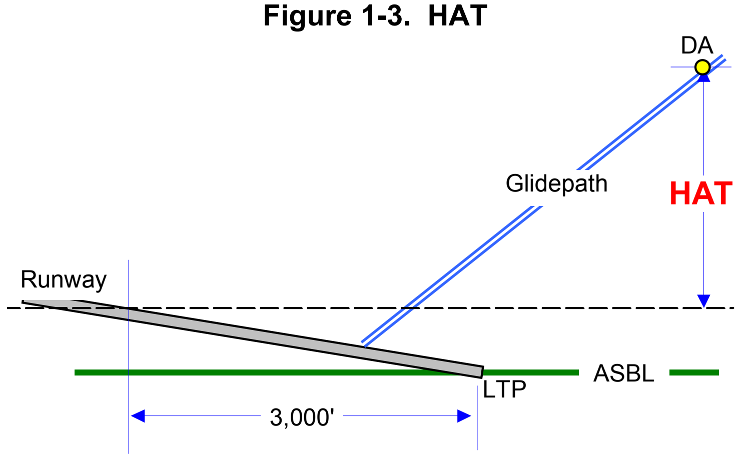
1.5.8 Glidepath Qualification Surface (GQS).

The GQS is a narrow inclined plane centered on the runway centerline that limits the height of obstructions between the DA and LTP.

1.5.9 Height Above Touchdown (HAT).

The HAT is the height of the DA above the highest point in the first 3,000 feet of the landing runway (touchdown zone elevation). See figure 1-3

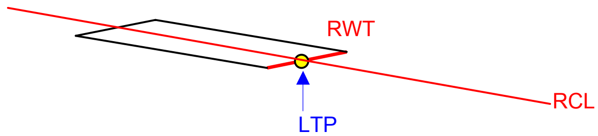
Figure 1-3. HAT



1.5.10 Landing Threshold Point (LTP).

The point where the runway centerline (RCL) intersects the runway threshold (RWT) is known as the LTP. It is defined by WGS 84/NAD 83 latitude, longitude, and orthometric height (MSL elevation). See figure 1-4.

Figure 1-4. LTP



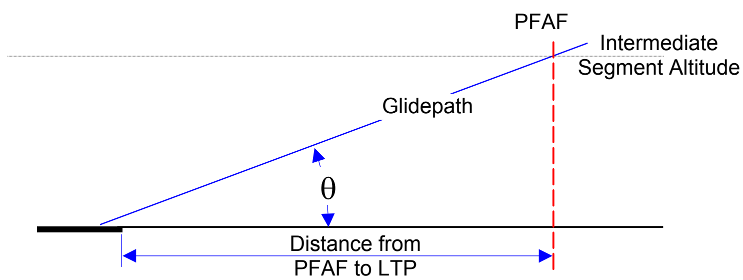
1.5.11 Obstacle Clearance Surface (OCS).

The OCS is an inclined surface with a slope ratio dependent on the glidepath angle of a precision approach or an approach procedure with vertical guidance (APV). The separation between this surface and the glidepath at any given distance from GPI defines the MINIMUM required obstruction clearance at that point.

1.5.12 Precision Final Approach Fix (PFAF).

A 2-dimensional (2D) point located on the final approach course at the point the glidepath intercepts the intermediate segment altitude (glidepath intercept altitude). The PFAF marks the beginning of the precision FAS (see figure 1-5).

Figure 1-5. PFAF



1.5.13 Required Navigation Performance (RNP).

RNP is a statement of the navigational performance required to maintain flight within a given airspace.

1.5.14 Required Obstacle Clearance (ROC).

ROC is the MINIMUM amount (in feet) of vertical clearance that must exist between aircraft and ground obstructions at a specific point in an instrument procedure. ROC is provided through application of level and sloping OCS's.

1.5.15 Runway Threshold (RWT).

The RWT marks the beginning of the portion of the runway usable for landing (see figure 1-6). It extends the full width of the runway. The LTP geographic coordinates identify the point the runway centerline crosses the RWT.

Figure 1-6 Threshold

1.5.16 Special Aircraft and Aircrew Authorization Required (SAAAR).

It is possible to equip aircraft beyond the minimum standard and to train aircrews to achieve a higher level of performance. These higher levels of equipage and overall performance are the basis of expanded RNP capability. Procedures that incorporate this expanded capability will contain a minima line that requires special authorization for use.

1.5.17 Visual Glide Slope Indicator (VGSI).

The VGSI is an airport lighting aid that provides the pilot a visual indication of the aircraft position relative to a specified glidepath to a touchdown point on the runway.

1.6 INFORMATION UPDATE.

For your convenience, FAA Form 1320-19, Directive Feedback Information, is included at the end of this order to note any deficiencies found, clarifications needed, or suggested improvements regarding the contents of this order. When forwarding your comments to the originating office for consideration, please use the "Other Comments" block to provide a complete explanation of why the suggested change is necessary.

CHAPTER 2. GENERAL CRITERIA

2.0 POLICY DIRECTIVES.

Orders 8260.3, United States Standard for Terminal Instrument Procedures (TERPS); 8260.19, Flight Procedures and Airspace; 8260.38, Civil Utilization of Global Positioning System (GPS); 8260.44, Civil Utilization of Area Navigation (RNAV) Departure Procedures; 8260.45, Terminal Arrival Area (TAA) Design Criteria; and 7130.3, Holding Pattern Criteria, apply unless specified otherwise in this order. The final and missed approach criteria described in this order supersede the other publications listed above, except as noted.

2.1 DATA RESOLUTION.

Perform calculations using at least 0.01 unit of measure accuracy. Use double precision (calculation accuracy to at least 13 decimal places) where calculation is accomplished by automated means. The following list specifies the minimum accuracy standard for documenting data expressed numerically. This standard applies to the documentation of final results only; e.g., a calculated adjusted glidepath angle of 3.04178° is documented as 3.05°. The standard does not apply to the use of variable values during calculation. Use the most accurate data available for variable values.

**Do not round intermediate results. Round only the final result of calculations for documentation purposes.*

2.1.1 Documentation Accuracy:

2.1.1 a. **WGS-84/NAD-83 latitudes and longitude**s to the nearest one hundredth (0.01) arc second;

2.1.1 b **LTP MSL elevation** to the nearest foot,

2.1.1 c. **LTP height above ellipsoid (HAE)** to the nearest tenth (0.1) meter;

2.1.1 d. **Course width at threshold** to the nearest quarter (0.25) meter;

2.1.1 e. **Glidepath angle** to the next higher one hundredth (0.01) degree;

2.1.1 f. **Courses** to the nearest one hundredth (0.01) degree; and

2.1.1 g. **Distances** to the nearest hundredth (0.01) unit.

**Use the documented rounded values in paragraphs 2.1.1a through f in calculations*.

2.1.2 Mathematics Convention.

2.1.2 a. Definition of Mathematical Functions.

$a + b$ indicates addition
$a - b$ indicates subtraction
$a \times b$ or ab indicates multiplication
$\frac{a}{b}$ or a/b or $a \div b$ indicates division
$(a - b)$ indicates the result of the process within the parenthesis
$|a - b|$ indicates absolute value
$\approx$ indicates approximate equality
$\sqrt{a}$ indicates the square root of quantity "a"
a^2 indicates $a \times a$
$tan(a)$ indicates the tangent of "a" degrees
$tan^{-1}(a)$ indicates the arc tangent of "a"
$sin(a)$ indicates the sine of "a" degrees
$sin^{-1}(a)$ indicates the arc sine of "a"
$cos(a)$ indicates the cosine of "a" degrees
$cos^{-1}(a)$ indicates the arc cosine of "a"

2.1.2 b. Operation Precedence (Order of Operations).

First: Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.
Second: Functions: Tangent, sine, cosine, arcsine and other defined functions
Third: Exponentiations: powers and roots
Fourth: Multiplication and Division: products and quotients
Fifth: Addition and subtraction: sums and differences
e.g,
$5 - 3 \times 2 = -1$ because multiplication takes precedence over subtraction
$(5 - 3) \times 2 = 4$ because parentheses take precedence over multiplication
$\frac{6^2}{3} = 12$ because exponentiation takes precedence over division
$\sqrt{9 + 16} = 5$ because the square root sign is a grouping symbol
$\sqrt{9} + \sqrt{16} = 7$ because roots take precedence over addition
$\frac{sin(30°)}{0.5} = 1$ because functions take precedence over division
$sin\left(30°/0.5\right) = 0.8660254$ because parentheses take precedence over functions

<u>Note on calculator usage</u>: Most calculators are programmed with these rules of precedence. When possible, let the calculator maintain all of the available digits of a number in memory rather than re-entering a rounded number. For highest accuracy from a calculator, any rounding that is necessary should be done at the latest opportunity.

2.2 RNP SEGMENT CONSTRUCTION GENERAL INFORMATION.

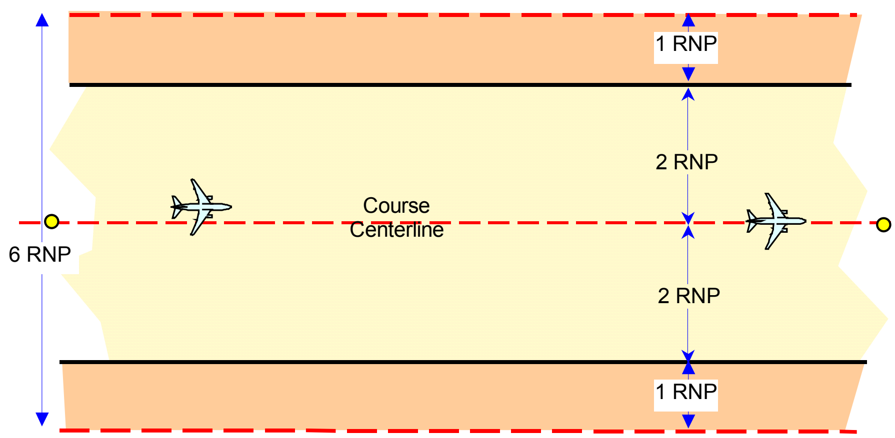
Parallel lines normally bound obstruction clearance areas associated with RNP (see figures 2-1A and 2-1B). Turns are normally accomplished at fly-by fixes. Turns are limited to 120° or less at and below flight level 190, 70° or less above flight level 190.

2.2.1 Segment Width.

See table 2-1 for applicable RNP-levels.

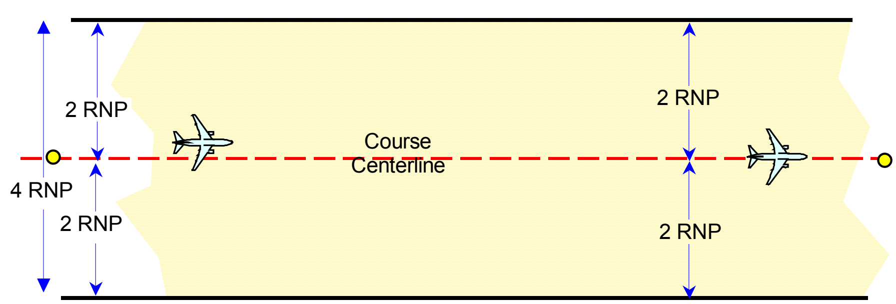
2.2.1 a. **BASIC**. Primary area: $\frac{1}{2}\mathbf{Width_{primary}} = 2 \times \mathbf{RNP}$,
Secondary area: $\mathbf{Width}_{\text{secondary}} = 1 \times \mathbf{RNP}$. (see figure 2-1A).

Figure 2-1A. BASIC RNP Segment Width



2.2.1 b. **ADVANCED.** Primary area: $\frac{1}{2}\mathbf{Width_{primary}} = 2 \times \mathbf{RNP}$. There are no secondary areas (see figure 2-1B).

Figure 2-1B. ADVANCED RNP Segment Width



2.2.2 Segment ROC.

The ROC varies according to segment type (initial, intermediate, etc.). See figures 2-2A and 2-2B and table 2-1.

Table 2-1. Typical BASIC RNP-levels and ROC Values#

SEGMENT	RNP-LEVEL (NM)	ROC VALUE	PRIMARY AREA WIDTH
En Route	2.0	1000*	8.0 NM (±4.0)
Initial	1.0	1000	4.0 NM (±2.0)
Intermediate	1.0	500	4.0 NM (±2.0)
Final	0.3	**	1.2 NM (±0.6)
Missed Approach	1.0	**	4.0 NM (±2.0)

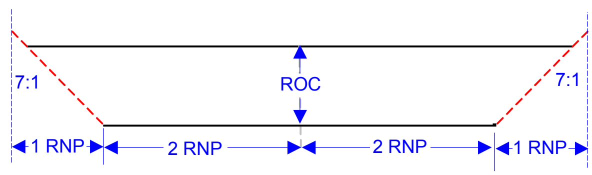
** 2000 in designated mountainous terrain. Volume 1, paragraph 1720 applies*

*** Variable for final descent and missed approach climb, see appropriate section.*

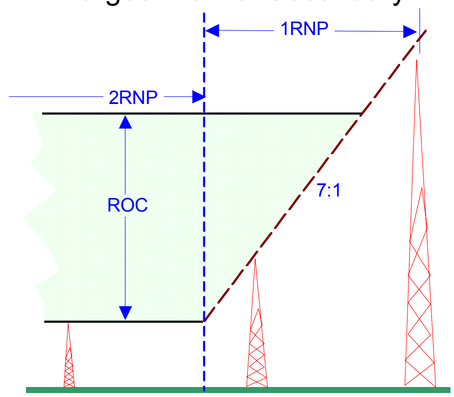
2.2.2 **a. BASIC**. Minimum altitude determination using primary and secondary ROC (see figure 2-2A).

NOTE: The secondary transitional surface 7:1 rise varies with RNP-level. For instance, the surface rises 260.4 feet for an RNP-level of 0.3, and 868 feet for an RNP-level of 1.0.

Figure 2-2A. RNP Segment ROC
Segment Cross Section



Enlarged View of Secondary



2.2.2 **a. (1) Primary area.** Determine the minimum altitude (**A**) value prior to rounding using formula 2.1:

Minimum Altitude Calculation

Formula 2.1

$$\mathbf{A} = \mathbf{h} + (\mathbf{ROC} + \mathbf{a})$$

Where h = MSL height of obstacle (or equivalent height from 2.2.2a(2))
ROC = ROC value from table 2-1
a = TERPS Volume 1, paragraph 323 adjustments (if appropriate)

2.2.2 **a. (2) Secondary area**. Use formula 2.2 to reduce the height of a secondary obstacle to an equivalent height applicable to the primary area. If evaluating the obstacle with ROC, use the equivalent height value for **h** in formula 2.1. If evaluating the final segment secondary area, apply the equivalent height of the obstacle as value **h** in paragraph 4.5.3.

Formula 2.2

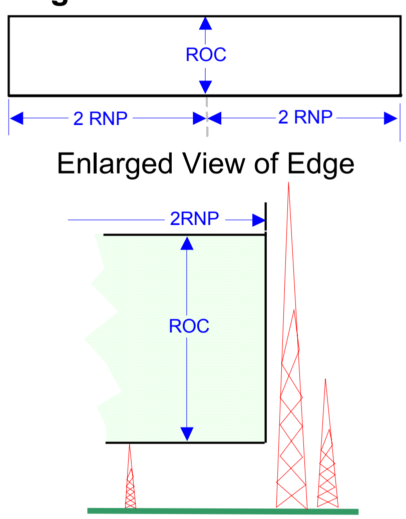
$$\textbf{equivalent height} = \mathbf{h} - \frac{\mathbf{d_P}}{7}$$

where d_p = distance from edge of primary measured perpendicular to course

2.2.2 **b. ADVANCED**. Minimum altitude determination using primary ROC (see figure 2-2B).

Figure 2-2B. RNP Segment ROC

Segment Cross Section



Determine the minimum altitude (**A**) value prior to rounding using formula 2.1 above.

2.2.3 Segment Leg Types.

RNP procedures are constructed by connecting segment legs together. A segment is identified by the method used to define the lateral path and how the segment terminates. There are several leg types available for RNAV operations. Five leg types are identified below; however, only one will be utilized in the first edition of these criteria. Additional leg types will be implemented in future changes to this order. Leg types are often identified by a two-letter acronym. These acronyms are a set of defined codes referred to as Path Terminators. Each code defines a specific type of flight path and a specific type of termination of flight path. For example, a TF leg is a great circle track between two known fixes and terminates at a fix, while a VA (Heading-to-Altitude) or HA (Hold-to-Altitude) terminates at an altitude.

2.2.3 a. BASIC.

2.2.3 **a (1) Straight Route Segment [track to a fix (TF) leg].** A straight flight path between two fixes. The first fix is either the previous leg termination fix or the initial (first) fix of a procedure (see figure 2-3).

Figure 2-3. Track to a Fix (TF) Leg Type

2.2.3 b. ADVANCED

2.2.3 **b. (1) Radius to Fix (RF) Segment.** RESERVED

2.2.3 **b. (2) Hold to Fix (HF) Route Segment.** RESERVED

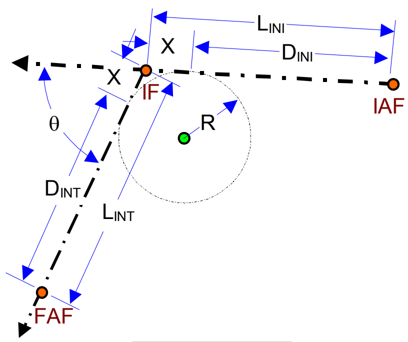
2.2.3 **b. (3) Hold to Altitude (HA) Route Segment**. RESERVED

2.2.3 **b. (4) Hold to Manual (HM) Terminal Route Segment.** RESERVED

2.2.4 Calculation of Descent Gradient[(2)].

2.2.4 a. Calculating Descent Distance (D). Where a turn is required at the **IF**, calculate the initial and intermediate segment descent distances as depicted in figure 2-4. Refer to formula 2.5 to calculate turn radius (**R**) values.

Figure 2-4. Calculating Descent Distance (D)



Formula 2.3

$$\mathbf{X} = \mathbf{R}\tan\left(\theta/2\right)$$

$$\mathbf{D} = \mathbf{L} - \mathbf{X}$$

$D = D_{INI}$ or D_{INT} as appropriate in NM
$L = L_{INI}$ or L_{INT} as appropriate in NM
θ = Degrees of heading change

EXAMPLE

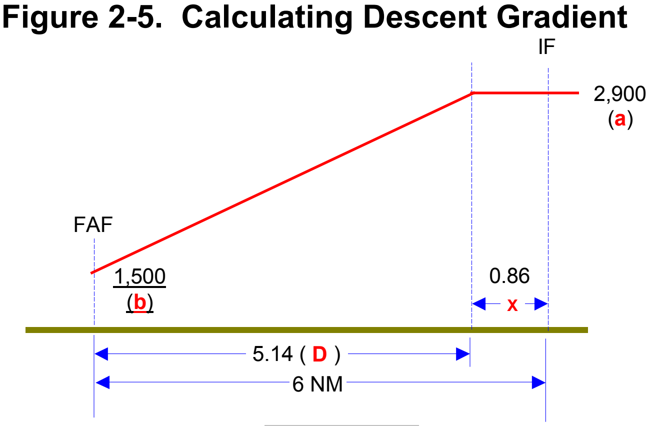
L=6 NM θ=60° Alt=6000 CAT D/E

R=1.49 (See formula 2.5)

$$D=6-\left[1.49\tan\left(60/2\right)\right] \quad D=5.14\text{ NM}$$

2.2.4 **b. Calculating Descent Gradient (DG).** Determine total altitude lost between the plotted positions of the IAF and IF or IF and FAF in feet as appropriate. Determine the distance (D) in NM available for descent (see formula 2.3). Divide the total altitude lost by D to determine the segment descent gradient (see formula 2.4 and figure 2-5).

Figure 2-5. Calculating Descent Gradient



Formula 2.4

$$\mathbf{DG} = \frac{\mathbf{a - b}}{\mathbf{D}}$$

Example

$$\frac{2{,}900-1{,}500}{5.14} = 272$$

2.2.5 Determining Turning Flight Track Radius[3].

Calculate the flight track turn radius using formula 2.5:

Formula 2.5

$$V_{KTAS} = 0.00002(\textbf{altitude})V_{KIAS} + V_{KIAS}$$
$$R = V_{KTAS} \times 0.005305$$

Using the following indicated airspeeds in the specified segments (convert to true airspeed using formula 2.5 above):

Final Approach Segment
Cat A-90, Cat B-120, Cat C-140, Cat D-165, Cat E->165 (specify)

Initial/intermediate Segments
Cat A-150, Cat B-180, Cat C-240, Cat D/E-250

NOTE: Use the highest published category for the procedure.

2.2.6 Fly-By Fix Turn Inner Boundary Expansion, Outer Boundary Construction.

2.2.6 a. BASIC. See figure 2-6A.

RNAV turns are usually accomplished at fly-by or fly-over fixes. Fly-over fixes are not recommended in RNP segments. Turns at fly-by fixes require an expanded area on the inside of the turn to protect the ground track inside the fix. Construct the expanded inner boundary using the steps:

STEP 1: Draw a line bisecting the turn angle. The origin of all arc radii will be on this line. Using the appropriate turn radius (**R**) from formula 2.5, draw an arc tangent to the course to and from the turn fix.

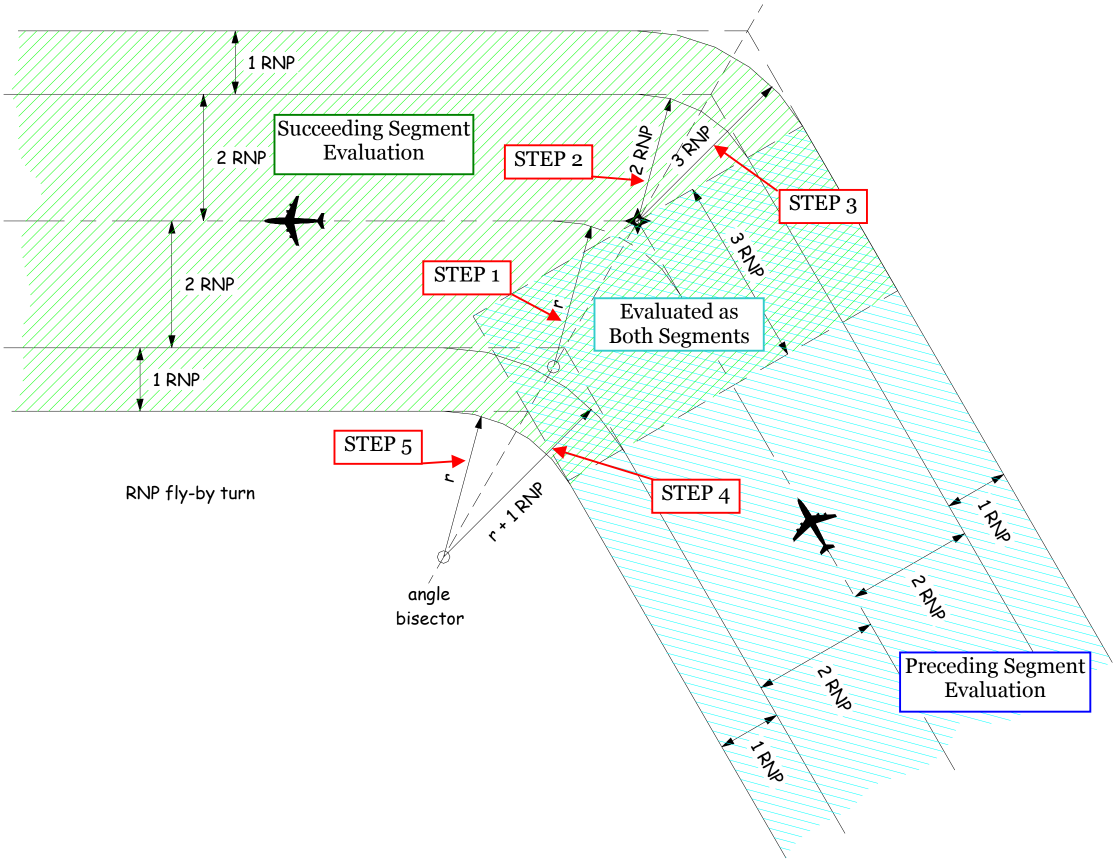
STEP 2: Using the turn fix as the origin, draw an arc of radius **2 RNP** tangent to the outer boundary lines of the preceding and succeeding segments.

STEP 3: Using the turn fix as the origin, draw an arc of radius **3 RNP** tangent to the secondary area boundary lines of the preceding and succeeding segments.

STEP 4: Using a radius of **R+RNP**, draw an arc tangent to the inner boundary line of the preceding and succeeding segments.

STEP 5: Using the arc origin from step 4, draw an arc of radius **R** tangent to the secondary area boundary lines of the preceding and succeeding segments.

Figure 2-6A. Inside Turn Expansion at Fly-By Fixes



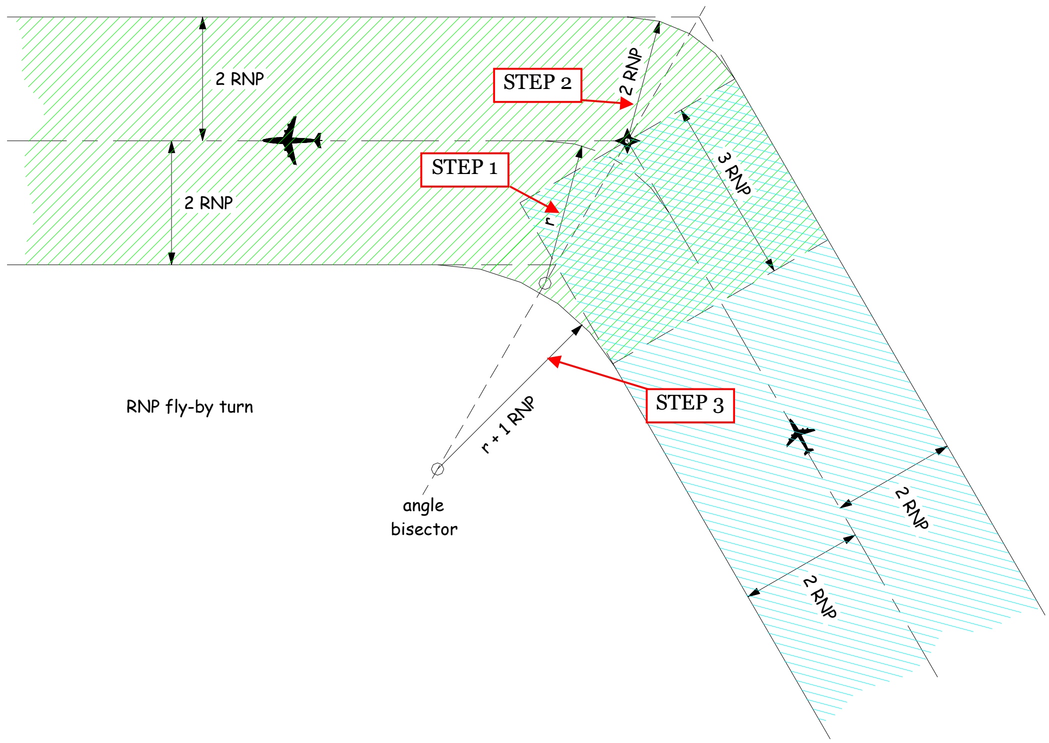
2.2.6 **b. ADVANCED.** See figure 2-6B.

STEP 1: Draw a line bisecting the turn angle. The origin of all arc radii will be on this line. Using the appropriate turn radius (**R**) from formula 2.5, draw an arc tangent to the course to and from the turn fix.

STEP 2: Using the turn fix as the origin, draw an arc of radius **2 RNP** tangent to the outer boundary lines of the preceding and succeeding segments.

STEP 3: Using a radius of **R+RNP**, draw an arc tangent to the inner boundary line of the preceding and succeeding segments.

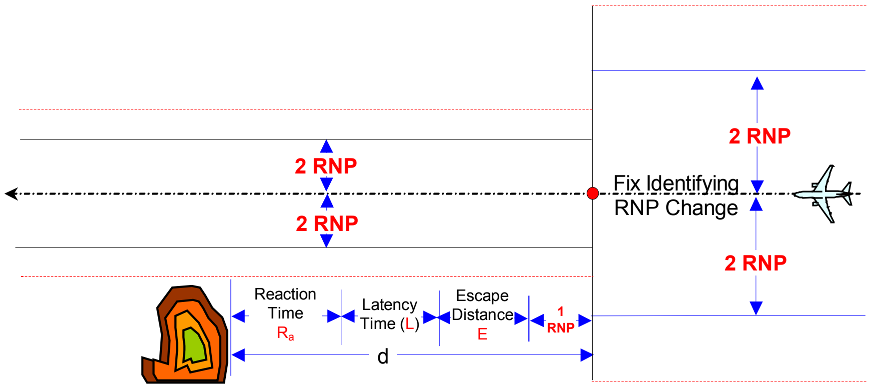
Figure 2-6B. Inside Turn Expansion at Fly-By Fixes

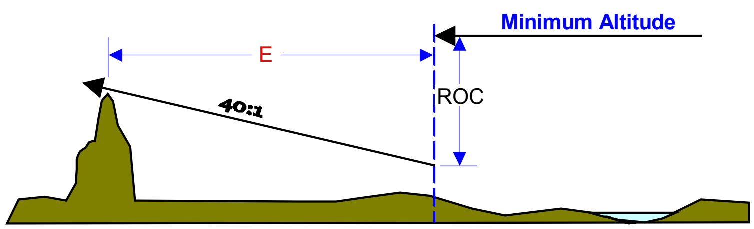


2.2.7 Joining Segments of Differing RNP-Levels[(4)].

A lower RNP level may yield lower segment altitudes since the obstacle evaluation area is smaller thus contains fewer obstacles, but the controlling obstacle is often close to the course line. Therefore, use the largest appropriate level possible in the intermediate and final approach segments consistent with desired minimums in order to curtail construction of ground obstructions in the vicinity of the final approach course. Design procedures requiring RNP-level changes between the IAF and MAP to change levels in straight segments. The location of the fix marking RNP-level reduction should be based on the point where the lower RNP-level is required. Locate the fix distance (**d**) from this point to assure appropriate alerting can be provided prior to the time that the lower RNP-level is needed considering the along-track error of the larger of the 2 segments (1×RNP), maximum latency (**L**) of RNP alerting messages, maximum ground speed, crew response time (**R_a**), and distance (**E**) required to clear obstacles immediately beyond the fix (see figure 2-7 and table 2-2).

Figure 2-7. Changing to Smaller RNP-levels





The distance required to clear an obstruction is determined by applying a 40:1 OCS starting at a height equal to the preceding segment minimum altitude minus the required ROC including adjustments. Determine distance **E** (NM) using formula 2.6.

Formula 2.6

$$\mathbf{a} = (\mathbf{B} - \mathbf{C})$$

$$\text{if } \mathbf{O_{MSL}} \le \mathbf{a} \text{ then } \mathbf{E} = 0$$

$$\text{if } \mathbf{O_{MSL}} > \mathbf{a} \text{ then } \mathbf{E} = \frac{(\mathbf{O_{MSL}} - \mathbf{a})40}{6076.11548}$$

Where a = MSL height of engine out surface
B = Minimum Segment Altitude
C = ROC plus adjustments of succeeding segment
O_{MSL} = MSL elevation of obstacle

Example

$$3{,}200 - 500 = 2{,}700 \quad (a)$$

$$\mathbf{O_{MSL}} = 2{,}949 \quad \therefore \quad \mathbf{O_{MSL}} > a$$

$$\frac{(2{,}949 - 2{,}700)40}{6076.11548} = 1.64$$

Table 2-2. Minimum Fix Distance (d) Variables
(Use values for the largest published category)

Category	Latency(L) in seconds	Reaction(R_a) in seconds
A	15	25
B	15	25
C	15	25
D	15	25
E	15	25

Determine **d** using formula 2.7

Formula 2.7

$$\mathbf{d} = \frac{\mathbf{k_{TAS}}}{3600}\mathbf{L} + \frac{\mathbf{k_{TAS}}}{3600}\mathbf{R_a} + \mathbf{E} + (1 \times \mathbf{RNP})$$

Since **L** and $\mathbf{R_a}$ are consistent for each category, the equation may be reduced to formula 2.8 for simplicity.

Formula 2.8

$$\mathbf{d} = \mathbf{k_{TAS}} \times 0.01111 + \mathbf{E} + (1 \times \mathbf{RNP})$$

CHAPTER 3. INITIAL AND INTERMEDIATE SEGMENTS

3.0 INITIAL AND INTERMEDIATE SEGMENTS.

An RNP approach procedure is a series of segment legs.

3.0.1 Alignment.

The geometry of the approach design is very flexible, allowing the RNAV "T" design configuration (see Order 8260.45), any GPS style configuration (see Order 8260.38A), or use of conventional instrument approach configuration (VOR, ILS, etc.) within the limitation of installed equipment.

3.0.1 a. **BASIC Alignment Limitations**. The MAXIMUM initial/intermediate segment intercept angle is 120°. The angle of intercept affects the MINIMUM intermediate segment length (see paragraph 3.0.2). The intermediate segment is an extension of the final approach course; i.e., a turn is not permitted at the FAF.

3.0.1 b. **ADVANCED Alignment Limitations**. **RESERVED**

3.0.2 Length.

3.0.2 a. **Initial Segment.** The length of the INITIAL segment must accommodate the descent required within the segment.

3.0.2 b. **Intermediate Segment**. The MINIMUM length of the INTERMEDIATE segment is dependent on, at least the following factors:

- The distance required to accommodate any change in RNP value between the initial segment width and the final segment width (see paragraph 2.2.7).
- The change (in degrees) from the initial course to the intermediate course (see table 3-1).
- The amount of altitude loss required in the segment (see paragraph 3.0.5b).

Table 3-1. MINIMUM INTERMEDIATE COURSE LENGTH

ANGLE (DEGREES)	MINIMUM LENGTH (MILES) **CAT A/B**	**C/D/E**
90 – 96	5	6
>96 - 102	6	7
>102 -108	6	8
>108 -114	6	9
>114 - 120	7	10

3.0.3 **Width.** See paragraph 2.2.1

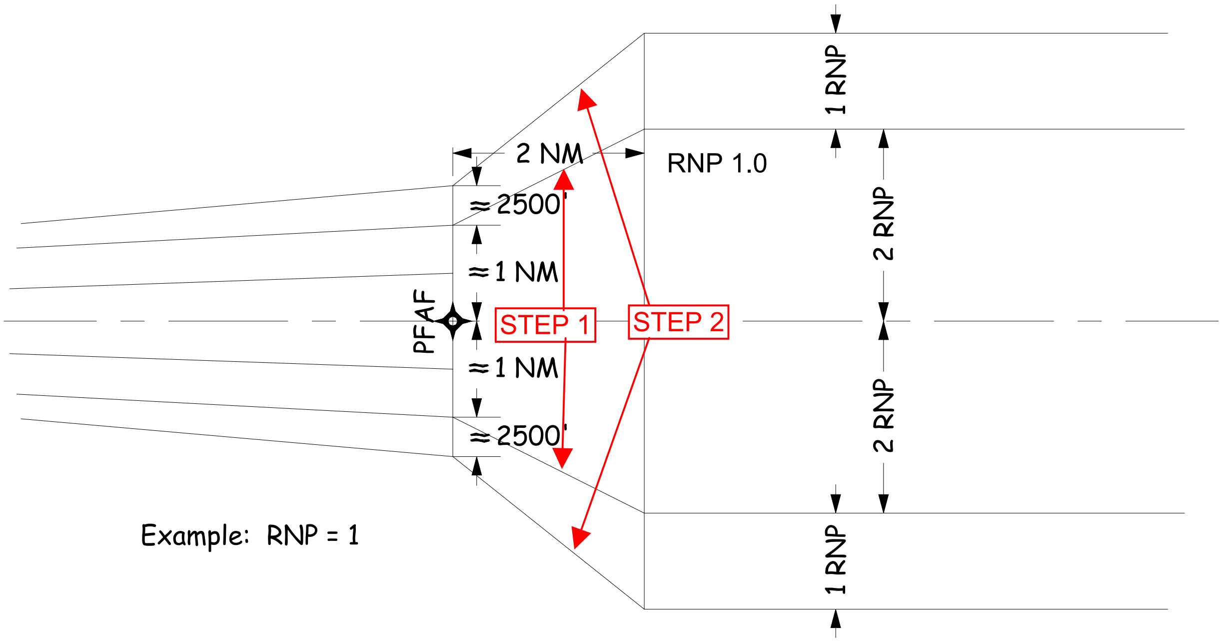
3.0.3 **a. BASIC Intermediate connection with precision final segment.** Connect the intermediate segment to the final segment as shown in figure 3-1A).[(5)]

STEP 1. From a point 2 NM prior to the PFAF, connect the intermediate area primary boundary to the "**X**" surface boundary line abeam the PFAF.

STEP 2. From a point 2 NM prior to the PFAF, connect the transition area outer boundary to the "**Y**" surface boundary line abeam the PFAF.

Figure 3-1A. BASIC Intermediate Connection to Precision Final Segment

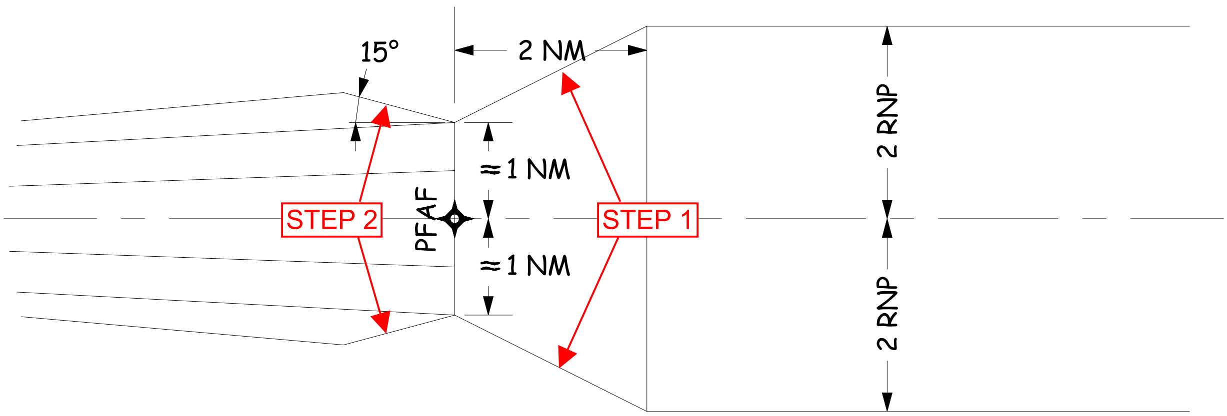
(Example RNP-Level 1.0 with intermediate segment secondary areas)



3.0.3 **b. ADVANCED Intermediate connection with precision final segment.** **STEP 1**. From a point 2 NM prior to the PFAF, connect the intermediate area primary boundary to the "**X**" surface boundary line abeam the PFAF (see figure 3-1B). **STEP 2**. From this point, draw a line splaying outward 15° relative to the final course to intersect the outer boundary of the Y surface.

Figure 3-1B. ADVANCED Intermediate Connection to Precision Final Segment

(Example No intermediate segment secondary areas)



3.0.4 Required Obstacle Clearance (ROC).

Establish the MINIMUM altitudes in the en route, feeder, initial, and intermediate segments by adding ROC and adjustments to the obstruction elevation. The resulting value may be rounded up or down to the nearest 100-foot increment if the rounded value provides at least MINIMUM ROC; i.e., 1,749 feet may round to 1,700 feet, and 1,750 feet may round to 1,800 feet. If a value is rounded down and the resulting value does not provide MINIMUM ROC, then the original value must be rounded up.

3.0.4 **a. Initial Segment ROC.** MINIMUM ROC is 1,000 feet plus adjustments required by TERPS Volume 1, paragraph 323.

3.0.4 **b. Intermediate Segment ROC**. MINIMUM ROC is 500 feet plus adjustments required by TERPS Volume 1, paragraph 323.

3.0.5 Descent Angle/Gradient.

The following OPTIMUM and MAXIMUM descent gradients apply. The flexibility offered by MAXIMUM and MINIMUM values may adversely affect the flyability of the approach procedure. Therefore, do not apply MAXIMUM descent gradients in segments of MINIMUM length.

3.0.5 **a. Initial Segment**.

- OPTIMUM 250 FT/NM (for high altitude penetrations 800)
- MAXIMUM 500 FT/NM (for high altitude penetrations 1,000)

3.0.5 **b. Intermediate Segment.**[6]

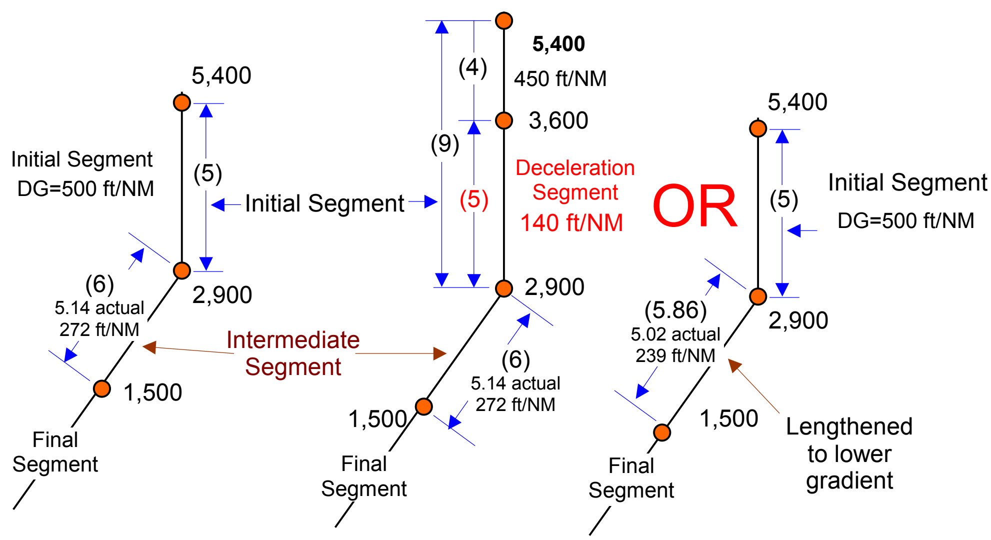
- OPTIMUM 150 FT/NM
- May require deceleration segment ≥ 240 FT/NM
- MAXIMUM 318 FT/NM

3.0.5 **c. Deceleration Segment** (applicable ONLY where minimums are published for category "C" or faster aircraft and a deceleration segment is deemed necessary). Where the intermediate segment descent gradient exceeds 240 ft/NM because of terrain or obstacles, a deceleration segment may be constructed in the initial segment. The MINIMUM deceleration length is dependent on segment descent gradient and magnitude of turn at the IF. The MAXIMUM allowable descent gradient in the deceleration segment is 150 ft/NM. Refer to table 3-2 to determine the minimum deceleration segment length (see figure 3-2 for examples).

Table 3-2. Minimum Deceleration Segment Length

Segment Descent Gradient (ft/NM)	Turn at IF ≤ 45° Minimum Length	Turn at IF >45° Minimum Length
0	2	4
75	3	4
150	5	5

Figure 3-2. Example of Deceleration Segment



CHAPTER 4. FINAL APPROACH SEGMENT (FAS)

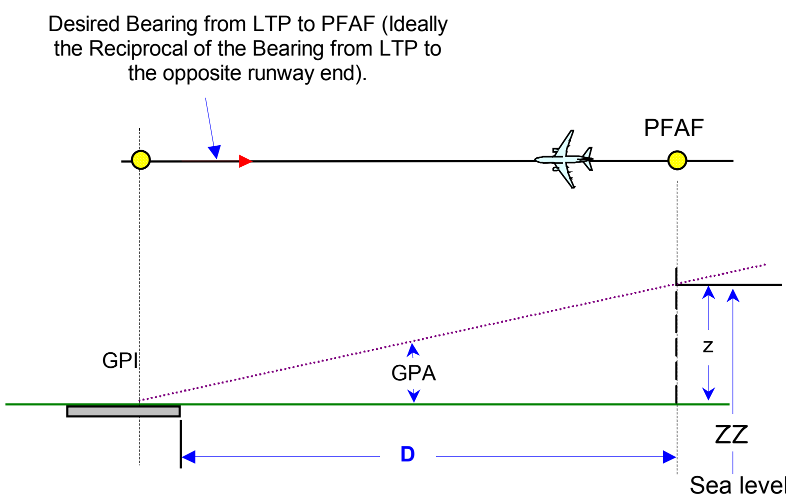
4.0 GENERAL.

4.0.1 **BASIC.** Vertical obstacle protection is based on the standard for baro-VNAV in TERPS Volume 3.

4.0.2 **ADVANCED.** Vertical obstacle protection based on variable vertical error budget. **RESERVED.**

4.1 DETERMINING PRECISION FINAL APPROACH FIX/FINAL APPROACH FIX (PFAF/FAF) COORDINATES (see figure 4-1).

Figure 4-1. Determining PFAF Distance to LTP



Geodetically calculate the latitude and longitude of the PFAF using the true bearing from the landing threshold point (LTP) to the PFAF and the horizontal distance (D_{PFAF}) from the LTP to the point the glidepath intercepts the intermediate segment altitude.

Determine D_{PFAF} using formulas 4.1 and 4.2:

Step 1: Formula 4.1

$$z = A - F$$

Example: $1537.70 = 2100 - 562.30$

Step 2: Formula 4.2

$$D_{PFAF} = 364{,}609\left[90 - \theta - \sin^{-1}\left(\frac{20{,}890{,}537 \times \sin(90+\theta)}{z + 20{,}890{,}537}\right)\right] - \frac{TCH}{\tan(\theta)}$$

{includes earth curvature}

Example

$$\mathbf{D_{PFAF}} = 364{,}609\left[90 - 3 - sin^{-1}\left(\frac{20{,}890{,}537 \times sin(90+3)}{1{,}537.7 + 20{,}890{,}537}\right)\right] - \frac{50}{tan(3)}$$

$$\mathbf{D_{PFAF}} = 364{,}609\left[87 - sin^{-1}\left(\frac{20{,}861{,}907.2451}{20{,}892{,}074.70}\right)\right] - \frac{50}{tan(3)}$$

$$\mathbf{D_{PFAF}} = 364{,}609\ [0.0794166528] - 954.05$$

$$\mathbf{D_{PFAF}} = 28{,}001.97$$

Where: A = FAF Altitude (example 2100)
F = LTP elevation (example 562.30)
θ = Glidepath angle (example 3.00°)

4.1.1 Determining Glidepath Altitude at a FIX.

Calculate the altitude (ZZ) of the glidepath at any distance (D_Z) from the ground point of intercept (GPI) using formula 4.3: *{includes earth curvature}*

Formula 4.3

$$\mathbf{ZZ} = \mathbf{LTP} + \frac{20{,}890{,}537 \times sin(90+\theta)}{sin\left(90 - \theta - \frac{\mathbf{D_Z} + \frac{\mathbf{TCH}}{tan(\theta)}}{364{,}609}\right)} - 20{,}890{,}537$$

Example

$$\mathbf{ZZ} = 562.30 + \frac{20{,}890{,}537 \times sin(90+3)}{sin\left(90 - 3 - \frac{28{,}956.03}{364{,}609}\right)} - 20{,}890{,}537$$

$$\mathbf{ZZ} = 562.30 + \frac{20{,}890{,}537 \times 0.9986295347}{0.9985560335} - 20{,}890{,}537$$

$$\mathbf{ZZ} = 2{,}100$$

Where: θ = Glidepath angle (example 3.00°)
D = Distance in feet from GPI to fix
LTP = Threshold elevation (MSL)
Z = Glidepath MSL altitude at fix

4.2 THRESHOLD CROSSING HEIGHT (TCH).

Select the appropriate TCH from table 4-1. Publish a note indicating the visual glide slope indicator (VGSI) is not coincident with the RNP procedure glidepath angle (GPA) when the difference between VGSI angle and the procedure GPA is more than 0.2° or the difference between the VGSI TCH and the procedure's TCH is more than 3 feet.

NOTE: If an instrument landing system (ILS) serves the runway, use the ILS TCH and glidepath angle.

Table 4-1. TCH Requirements

Representative Aircraft Type	**Approximate Glidepath to Wheel Height**	**Recommended TCH ± 5 Feet**	**Remarks**
HEIGHT GROUP 1 General Aviation, Small Commuters, Corporate Turbojets, T-37, T-38, C-12, C-20, C-21, T-1, Fighter Jets	10 Feet or less	40 Feet	Many runways less than 6,000 feet long with reduced widths and/or restricted weight bearing which would normally prohibit landings by larger aircraft.
HEIGHT GROUP 2 F-28, CV-340/440/580, B-737, C-9, DC-9, C-130, T-43, B-2, S-3	15 Feet	45 Feet	Regional airport with limited air carrier service.
HEIGHT GROUP 3 B-727/707/720/757, B-52, C-135, C-141, C-17, E-3, P-3, E-8	20 Feet	50 Feet	Primary runways not normally used by aircraft with ILS glidepath-to-wheel heights exceeding 20 feet.
HEIGHT GROUP 4 B-747/767/777, L-1011, DC-10, A-300/320, B-1, KC-10, E-4, C-5, VC-25	25 Feet	55 Feet	Most primary runways at major airports.

Note 1: To determine the minimum allowable TCH, add 20 feet to the glidepath-to-wheel height.
Note 2: To determine the maximum allowable TCH, add 50 feet to the glidepath-to-wheel height.

4.3 GLIDEPATH ANGLE (GPA) (see table 4-2).

Table 4-2. Allowable Range of Glidepath Angles

	Descent Angle	Descent Gradient (FT/NM)
OPTIMUM	3.0°	318
MINIMUM	2.75°	292
MAXIMUM	3.5°	371

4.4 GLIDEPATH QUALIFICATION SURFACE (GQS).

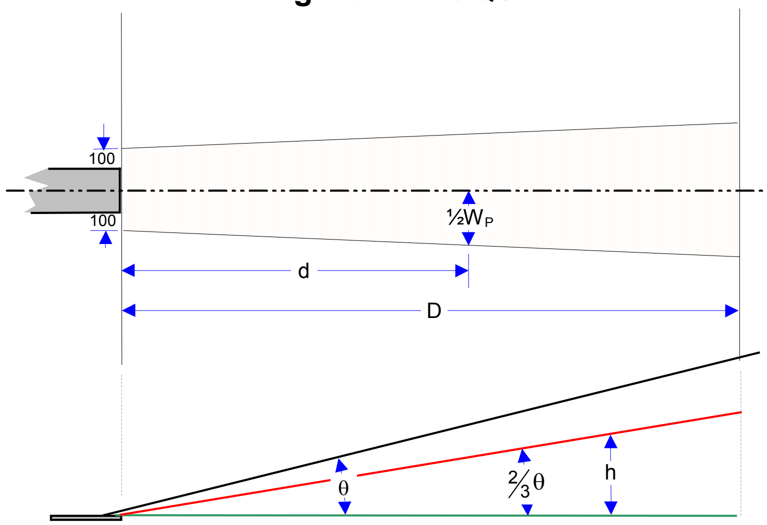
The GQS extends from the runway threshold along the runway centerline extended to the decision altitude (DA) point. It limits the height of obstructions between DA and runway threshold (RWT). When obstructions exceed the height of the GQS, an approach procedure with positive vertical guidance is not authorized (see figure 4-2).

4.4.1 Area.

4.4.1 **a. Length**. The GQS extends from the runway threshold to the DA point.

4.4.1 **b. Width**. The GQS originates 100 feet from the runway edge at LTP.

Figure 4-2. GQS



4.4.1 **b. (1) ½ Width at DA** ($\frac{1}{2}W_P@DA$).[7] Calculate the half-width of the GQS from the runway centerline extended at the DA point using formula 4.4:

Formula 4.4

$$\frac{1}{2}\mathbf{W_P}@\mathbf{DA} = 0.036(\mathbf{D_{DA}} - 200) + 400$$

Where: D_{DA} = the distance (ft) measured along RCL extended from LTP to the DA point
½ W_P = half-width (ft) of GQS area

4.4.1 **b. (2) ½ Width at any distance**. Calculate the half-width of the GQS at any distance "d" from RWT using formula 4.5 (see figure 4-2):

Formula 4.5

$$\frac{1}{2}\mathbf{W_P} = \left(\frac{\frac{1}{2}\mathbf{W_P}@\mathbf{DA} - \mathbf{k}}{\mathbf{D_{DA}}}\mathbf{d}\right) + \mathbf{k}$$

Where: D_{DA} = distance (ft) from LTP to the DA point
d = desired distance (ft) measured along RCL extended from LTP
w = GQS half-width at distance d
$\frac{1}{2}\mathbf{W_P}@\mathbf{DA}$ = GQS half-width at DA from paragraph 4.4.1b(1)

$$\mathbf{k} = \frac{\mathbf{RWT}\text{ width}}{2} + 100$$

4.4.1 **c. OCS**. Obstructions must not penetrate the GQS. Calculate the height of the GQS above the approach surface baseline (ASBL) at any distance "d" measured from RWT along the runway centerline (RCL) extended to a point abeam the obstruction (see figure 4-2) using formula 4.6:

Formula 4.6

$$h_{GQS} = \tan\left(\frac{2\theta}{3}\right)d$$

Where d = distance from LTP (ft)

θ = glidepath angle

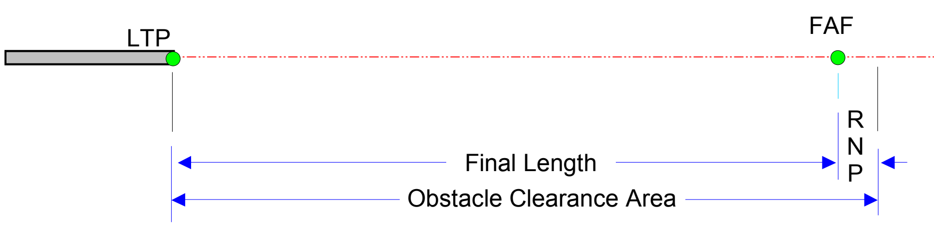
4.5 **FINAL SEGMENT.**

4.5.1 **Length and Alignment.**

The obstruction evaluation area begins at the along-track fix displacement value prior to the PFAF and extends to the LTP or missed approach point (MAP), whichever is encountered last (see figure 4-3). Align the final approach segment (FAS) with the runway centerline extended. Offset alignment is not authorized.

4.5.1 **a. ADVANCED.** Turns within Final Segment. RESERVED.

Figure 4-3. Final Approach Segment



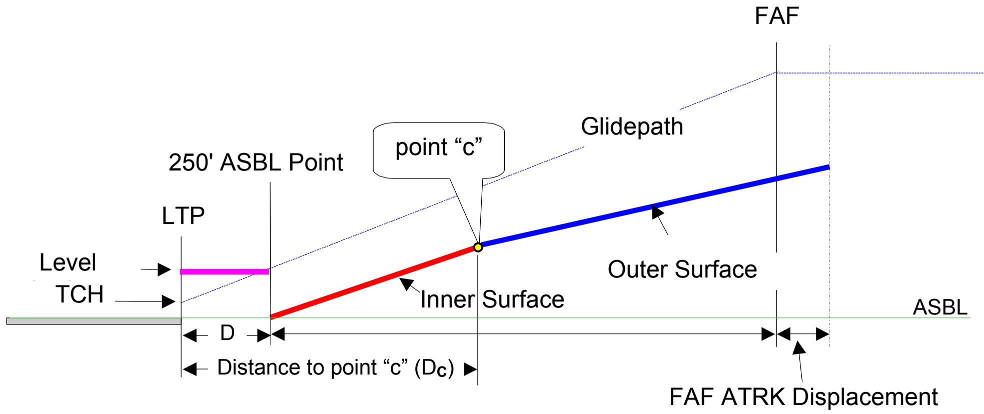
4.5.2 **Width.**

Segment width is dependent on the RNP value (see paragraph 2.2.1 for width requirements).

4.5.3 **Obstruction Clearance.**

Obstacle clearance is achieved by applying required obstacle clearance (ROC) or sloping obstacle clearance surfaces (OCS's) to the height of obstructions (or equivalent height if dealing with secondary areas per paragraph 2.2.2a(2)). See figure 4-4.

Figure 4-4. Final Segment OCS's



4.5.3 **a. Level Surface.**

The longitudinally level OCS overlies the area between the LTP and the point the glidepath reaches 250 feet above ASBL (distance "D_{250}"). See figures 4-4 and 4-5. Calculate distance "D_{250}" in feet from the LTP using formula 4.7:

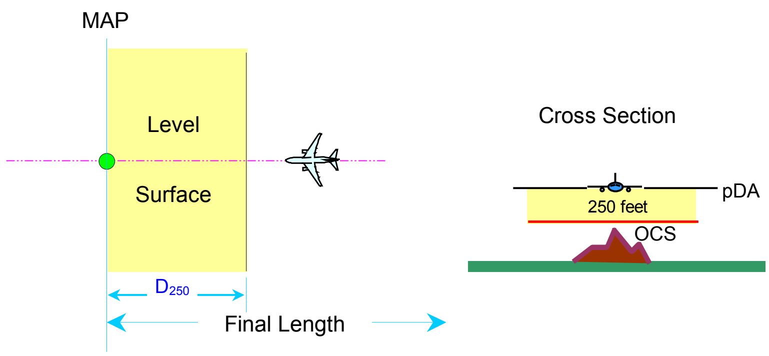
Formula 4.7

$$D_{250} = \frac{250 - TCH}{\tan(\theta)}$$

Example

$$\frac{250 - 53}{\tan(3)} = 3{,}758.98'$$

Figure 4-5. ROC Inside the 250 Feet Above ASBL Point



4.5.3 **a. (1) Preliminary DA (pDA).** Determine the pDA by adding 250 feet ROC value to the MSL elevation of the highest obstacle (**h**) in the level surface area (see paragraph 2.2.2).

4.5.3 **b. Sloping Surfaces.**

4.5.3 **b. (1) Inner Sloping Surface** (see figure 4-4). The inner surface begins at the point on the ASBL corresponding to the location of the 250 feet above ASBL point and extends to point "C". The standard temperature deviation from airport ISA temperature is –30° for the contiguous 48 states, -40° for Alaska, and –20° for Hawaii. If you use the standard deviation, skip to step 3. Otherwise, take the following steps to determine the value (S_I) of the inner slope:

STEP 1: Obtain the mean low temperature of the coldest month of the year for the last five years of data. If the data is given in Fahrenheit (°F), convert the temperature to Celsius (°C). Use formulas 4.8 and 4.9 to convert between Celsius and Fahrenheit temperatures:

Formula 4.8

$$°C = \frac{°\mathbf{F} - 32}{1.8}$$

Example

$$\frac{76-32}{1.8} = 24.44°C$$

Formula 4.9

$$°\mathbf{F} = (1.8 \times °\mathbf{c}) + 32$$

Example

$$(1.8 \times 24.44) + 32 = 75.99°\mathbf{F}$$

STEP 2: Convert the mean temperature into a deviation from International Standard Atmosphere (ISA) using formula 4.10, rounding to the lower whole degree:

Formula 4.10

$$\mathbf{deviation} = °\mathbf{C} - \left[15°\mathbf{C} - \left(\frac{\mathbf{Airport\ Elevation}}{500}\right)\right]$$

Example

$$-28 - \left[15°C - \left(\frac{1{,}528}{500}\right)\right] = -39.9°$$

STEP 3: Use this deviation or -15°C, whichever is lower, and the GPA to find the slope value from table 4-3.

STEP 4: Determine the Celsius temperature below which the procedure will not be authorized (T_{NA}) (see formula 4.11). Round the value to the nearest whole degree.

Formula 4.11

$$\mathbf{T_{NA}} = \left[15°\mathbf{C} - \left(\frac{\mathbf{Airport\ Elevation}}{500}\right)\right] - (\mathbf{value}\text{ from step 3})$$

Table 4-3. S_V Considering GPA and ISA Temperature Deviation

Glidepath ∠ →	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
ISA (°C) DEV ↓	**Slope Values**											
-15	23.8	23.0	22.2	21.6	20.9	20.3	19.8	19.3	18.8	18.3	17.9	17.5
-20	24.4	23.6	22.9	22.2	21.5	20.9	20.3	19.8	19.3	18.8	18.4	18.0
-25	25.1	24.3	23.5	22.8	22.1	21.5	20.9	20.4	19.9	19.4	18.9	18.5
-30	25.8	25.0	24.2	23.4	22.8	22.1	21.5	21.0	20.5	20.0	19.5	19.1
-35	26.6	25.7	24.9	24.1	23.4	22.8	22.2	21.6	21.1	20.6	20.1	19.6
-40	27.4	26.5	25.7	24.9	24.2	23.5	22.9	22.3	21.7	21.2	20.7	20.3
-45	28.2	27.3	26.5	25.7	24.9	24.2	23.6	23.0	22.4	21.9	21.4	20.9
-50	29.1	28.2	27.3	26.5	25.8	25.0	24.4	23.8	23.2	22.6	22.1	21.6

4.5.3 **b. (2) Outer Sloping Surface.** The outer surface begins at point "C" and ends at the along-track fix displacement value prior to the PFAF can be received (see figure 4-4).

STEP 1: **Outer Surface Slope Ratio (S_W).** Calculate the slope of the outer surface using formula 4.12:

Formula 4.12

$$S_W = \frac{102}{\theta}$$

STEP 2: **Calculate the distance (D_C)** from LTP to point C using formula 4.13:

Formula 4.13

$$D_C = \frac{(D_{250} S_W) - (200 S_V)}{(S_W - S_V)}$$

Where D_{250} = Distance from LTP to OCS origin from formula 4.7.
S_W = Slope of outer surface
S_V = Slope from table 4-3
θ = Glidepath Angle

4.5.3 c. Calculating the height of the OCS.

4.5.3 **c. (1) Inner OCS.** Calculate the height (I_Z) above ASBL of the inner surface using formula 4.14:

Formula 4.14

$$I_Z = \frac{D_o - D_{250}}{S_V}$$

Where D_O = the distance (ft) from RWT to the obstacle
D_{250} = the distance (ft) from the RWT to the inner surface origin (see paragraph 4.5.3a)

4.5.3 **c. (2) Outer OCS.** Calculate the height (O_Z) above ASBL of the outer OCS using formula 4.15:

Formula 4.15

$$O_Z = \frac{\theta(D_o - 200)}{102}$$

4.5.3 d. OCS Penetrations.

Obstructions should not penetrate the OCS. If the OCS is clear, publish the pDA value. If the height *(**h**) of the evaluated obstacle is greater than I_Z or O_Z as appropriate, the OCS is penetrated. Take one of the following actions. These actions are listed in order of preference.

ACTION 1: Remove or adjust the obstruction location and/or height.

ACTION 2: Raise glidepath angle.

ACTION 3: Adjust DA.

*Or equivalent height if in secondary transitional surface (see paragraph 2.2.2a(2)).

4.5.3 e. Adjustment of DA for Penetration of INNER SURFACE.

CASE 1: If the MSL elevation (**h**) of the obstacle is less than the elevation of point C ($C_{elevation}$): Use formulas 4.16 and 4.17.

Formula 4.16

$$C_{elevation} = LTP_E + \frac{D_C - D_{250}}{S_V}$$

Formula 4.17

$$DA_{adjusted} = LTP_E + \tan(\theta)\left(\left(D_O + \frac{TCH}{\tan(\theta)}\right) + (p \times S_V)\right)$$

Where θ = glidepath angle
D_O = distance (ft) to obstacle from LTP measured parallel to FAC
D_C = distance (ft) from LTP to point C (see formula 4.13)
p = amount of penetration (ft)
S_V = slope of inner surface from table 4-3
LTP_E = LTP elevation (ft)

CASE 2: If **h** is equal to or greater than the elevation of point C (see formula 4.18):

Formula 4.18

$$\mathbf{DA_{adjusted}} = \mathbf{LTP_E} + tan(\theta)\left[\left([\mathbf{h}-\mathbf{c}]\mathbf{S_W}\right) + \mathbf{D_C} + \frac{\mathbf{TCH}}{tan(\theta)}\right]$$

Where h = obstacle MSL elevation
c = elevation (MSL) of point C
S_W = Slope of outer surface (see formula 4.12)

4.5.3 **f. Adjustment of DA for penetration of OUTER SURFACE** (see formulas 4.19 and 4.20 and figure 4-6).

Formula 4.19

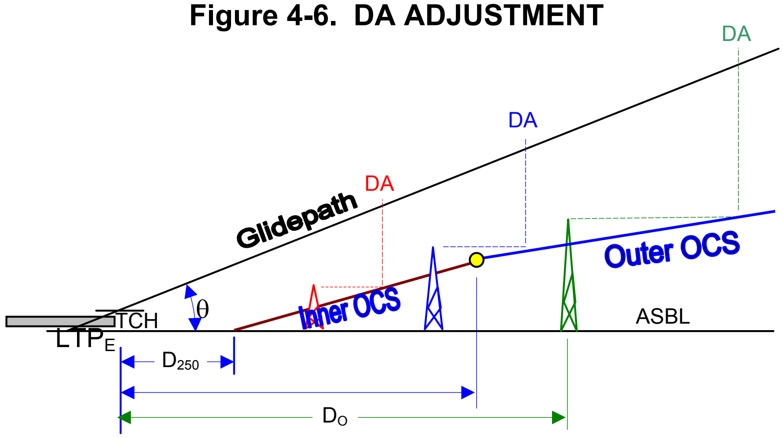
$$\mathbf{DA_{adjusted}} = \mathbf{LTP_E} + tan(\theta)\left[\left(\mathbf{pS_W}\right) + \mathbf{D_O} + \frac{\mathbf{TCH}}{tan(\theta)}\right]$$

Formula 4.20

$$\text{Distance LTP to } \mathbf{DA_{adjusted}} = \frac{\mathbf{DA_{adjusted}} - \mathbf{LTP_E}}{tan(\theta)} - \frac{\mathbf{TCH}}{tan(\theta)}$$

Where $DA_{adjusted}$ = Adjusted DA (MSL)

Figure 4-6. DA ADJUSTMENT



4.6 **ADVANCED FINAL SEGMENT VERTICAL SURFACES. RESERVED.**

4.7 **MINIMUMS.**

4.7.1 **BASIC.**

TERPS Volume 1, chapter 3 applies. Use table 9 as applied for localizer final to determine minimum visibility values.

4.7.2 **ADVANCED. RESERVED**.

CHAPTER 5. MISSED APPROACH SEGMENT (MAS)

5.0 GENERAL.(8)

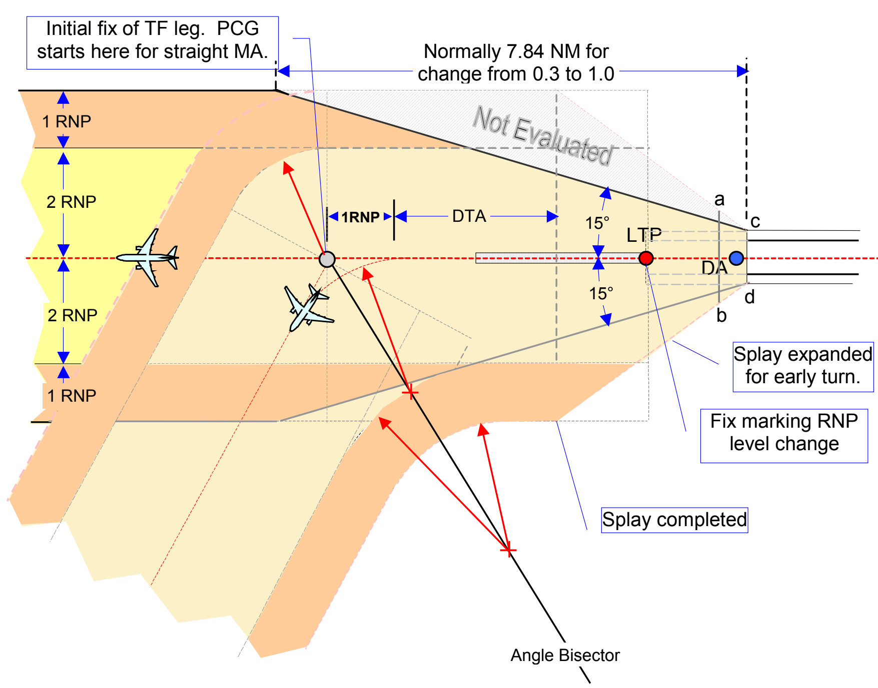
The MAS extends from the DA point to the missed approach clearance limit (an airway fix or a holding pattern from which an en route transition may be accomplished). Evaluate obstacles by application of a level surface containing the DA, followed by a 40:1 inclined surface (see figure 5-1). Height loss is assumed after DA. The fix marking the beginning of MAS RNP-level is normally located at the LTP. The fix may be located prior to the LTP to accommodate early turns.(8) Locate the fix identifying the start of the MAS RNP-level change at a point that is at least the along-track fix error value subsequent to the **ab** line (see figure 5-1).

5.1 SEGMENT WIDTH.

5.1.1 BASIC.

Segment width splays uniformly from FAS width to MAS width from the **cd** line (figure 5-1) to the MAS RNP-level at 15° relative to course (this takes 7.84 NM for a change from RNP 0.3 to RNP 1.0). For coding purposes, the LTP is assumed to mark the starting point of the MA RNP-level. If a turn is necessary before the splay is complete, expand the splay so it is complete RNP+DTA prior to the turn waypoint. The portion of the expanded splay on the side away from the turn is not evaluated (see turning area in figure 5-1). Locate the turn fix at least a distance equal to RNP+DTA after the **ab** line.

Figure 5-1. Missed Approach Area



5.1.2 **ADVANCED.** Maintaining final segment RNP-Level in missed approach segment. **RESERVED.**

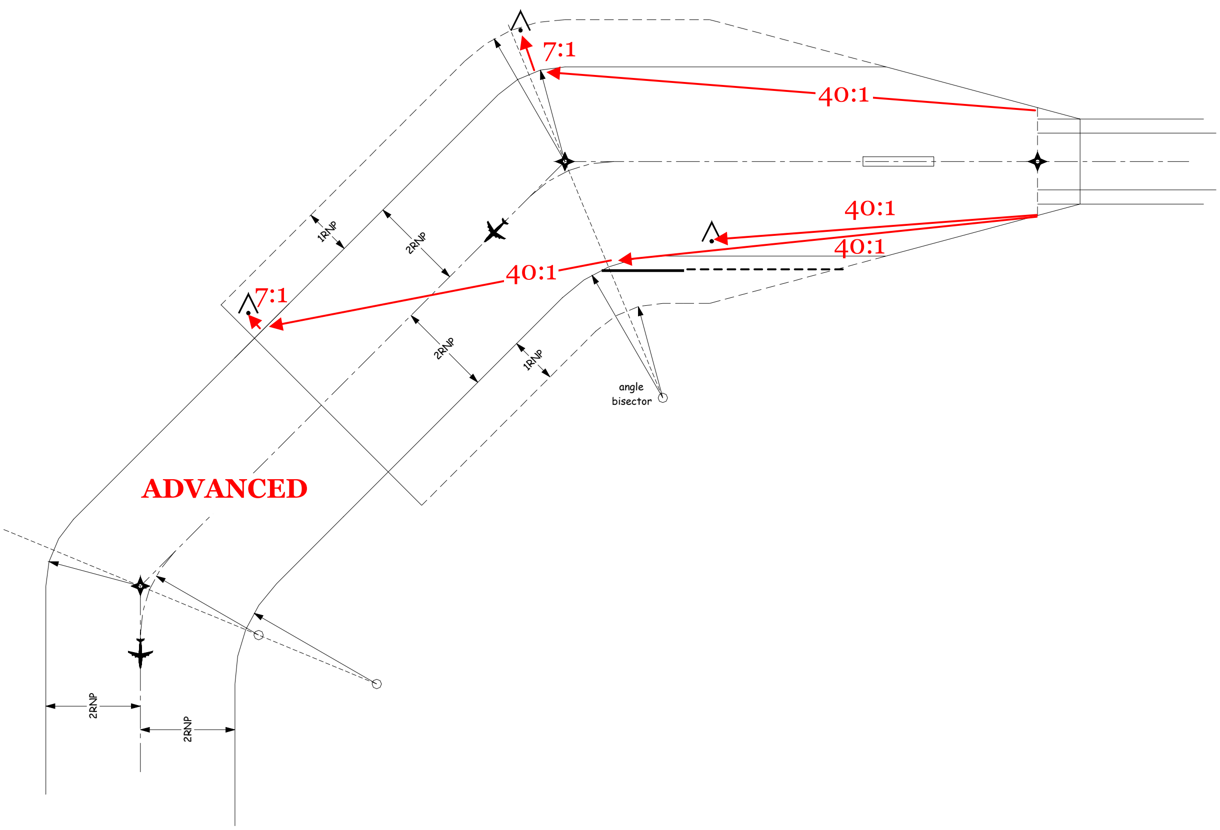
5.2 STRAIGHT MISSED APPROACH CONSTRUCTION.

Straight missed approach segments are constructed using TF leg segments. Secondary areas apply when positive course guidance is assured at the initial fix of the TF leg. In figure 5-1, this is the LTP. If the initial fix is not the LTP, it must be located within 5 NM of the **ab** line.

5.3 TURNING MISSED APPROACH.

The missed approach route is a series of segments. Turns are accomplished through application of TF segments connected at fly-by fixes (see figure 5-2).

Figure 5-2. Turning Missed Approach Surfaces (Fly-By Fix)



5.4 LEVEL OCS.

5.4.1 Length and Width.

A level surface overlies the area between **cd** and **ab** (see figure 5-3). The level surface accounts for possible along-track errors inherent with LNAV/VNAV. Calculate the distance (D_{cd}) from the LTP to the **cd** line, and the distance (D_{ab}) from LTP to the end of the level surface (**ab** line), using formulas 5.1 and 5.2.

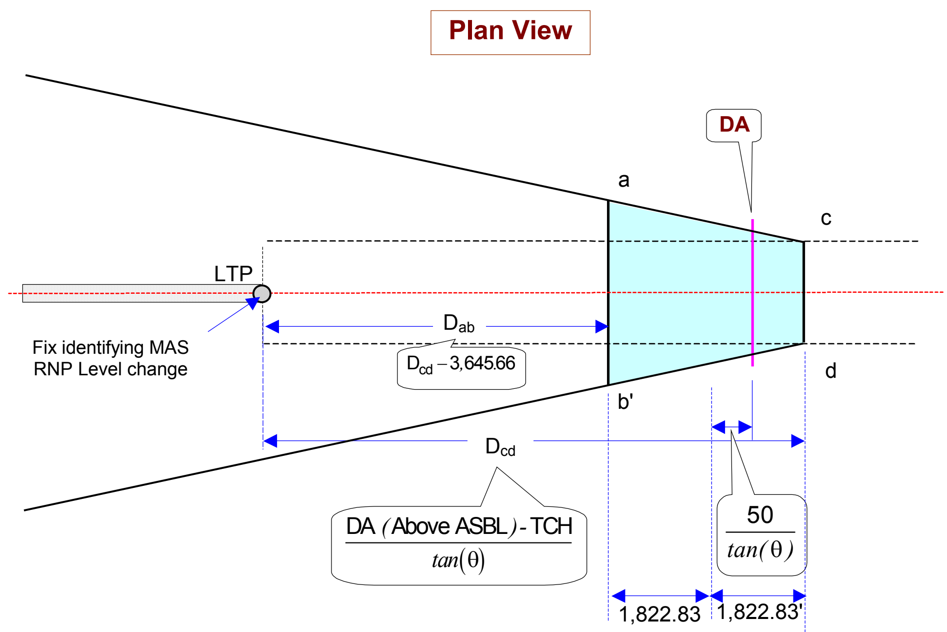
Formula 5.1

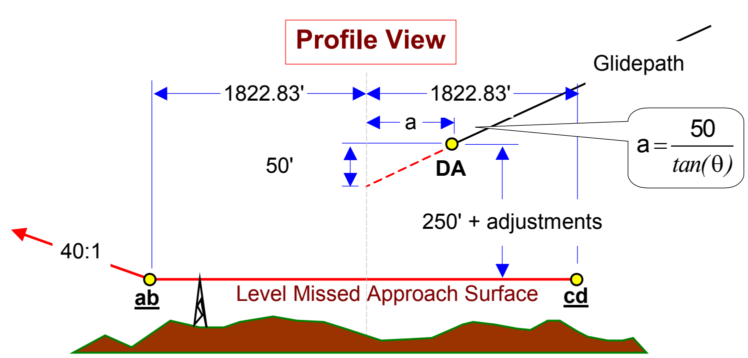
$$D_{cd} = \frac{DA(\text{above ABSL}) - TCH}{\tan(\theta)} - \frac{50}{\tan(\theta)} + 1{,}822.83$$

Formula 5.2

$$D_{ab} = D_{cd} - 3038.06$$

Figure 5-3. Level MA Surface





5.4.2 MA Level Surface Obstacle Clearance.

A MA level OCS overlies the area. The MSL height of the OCS ($h_{levelOCS}$) is determined by formula 5.3.

Formula 5.3

$$h_{levelOCS} = DA - (ROC + Adustments)$$

Where $h_{levelOCS}$ = MSL height of OCS
Adjustments = TERPS Volume 1, paragraph 323 adjustments

If the OCS is penetrated, raise the DA the amount of the penetration. Round the result to the next higher 20-foot increment.

5.5 40:1 SURFACE.

5.5.1 Length.

The 40:1 surface begins at the **ab** line. Calculate surface rise to the obstruction position based on the shortest distance from the obstruction to the **ab** line (see figure 5-2).

5.5.1 **a. If the clearance limit** is reached before the 40:1 OCS terminates, continue a climb-in-hold evaluation at the clearance limit.

5.6 OBSTACLE CLEARANCE.

Where obstructions penetrate the OCS, identify the obstruction with the greatest penetration. Increase the DA by the value ($DA_{adjustment}$) calculated by applying formula 5.4.

Formula 5.4

$$DA_{adjustment} = \frac{(40 \times p) \times \theta}{102}$$

Where p = amount of penetration in feet

5.7 MISSED APPROACH CLEARANCE LIMIT ALTITUDE.

5.7.1 Straight Missed Approach Procedures.

Use TERPS Volume 1, paragraphs 274b and d to establish the charted missed approach clearance limit altitude. Use TERPS Volume 1, paragraph 274c to determine if a climb-in-holding evaluation is required.

5.7.2 Combination Straight/Turning Missed Approach Procedures.

Use TERPS Volume 1, paragraphs 277d and f to establish the charted missed approach clearance limit altitude. Use TERPS Volume 1, paragraph 277e to determine if a climb-in-holding evaluation is required.

APPENDIX 1. FORMULAE USED IN RNP CRITERIA

Paragraph 2.2.2a(1). BASIC Primary Area.

Formula 2.1

$$\mathbf{A} = \mathbf{h} + (\mathbf{ROC} + \mathbf{a})$$

Paragraph 2.2.2a(2). BASIC Secondary Area.

Formula 2.2

$$\textbf{equivalent height} = \mathbf{h} - \frac{\mathbf{d_P}}{7}$$

Paragraph 2.2.4a. Calculating Descent Distance (D).

Formula 2.3

$$\mathbf{X} = \mathbf{R}\,tan(\theta/2)$$
$$\mathbf{D} = \mathbf{L} - \mathbf{X}$$

Paragraph 2.2.4b. Calculating Descent Gradient (DG).

Formula 2.4

$$\mathbf{DG} = \frac{\mathbf{a} - \mathbf{b}}{\mathbf{D}}$$

Paragraph 2.2.5. Calculating Turning Flight Track Radius.

Formula 2.5

$$\mathbf{V_{KTAS}} = 0.00002(\textbf{altitude})\mathbf{V_{KIAS}} + \mathbf{V_{KIAS}}$$
$$\mathbf{R} = \mathbf{V_{KTAS}} \times 0.005305$$

Paragraph 2.2.7. Joining Segments of Differing RNP-levels.

Formula 2.6

$$\mathbf{a} = (\mathbf{B} - \mathbf{C})$$
$$\text{if } \mathbf{O_{MSL}} \le \mathbf{a} \text{ then } \mathbf{E} = 0$$
$$\text{if } \mathbf{O_{MSL}} > \mathbf{a} \text{ then } \mathbf{E} = \frac{(\mathbf{O_{MSL}} - \mathbf{a})40}{6076.11548}$$

Formula 2.7

$$\mathbf{d} = \frac{\mathbf{k_{TAS}}}{3600}\mathbf{L} + \frac{\mathbf{k_{TAS}}}{3600}\mathbf{R_a} + \mathbf{E} + (1\mathbf{xRNP})$$

Formula 2.8

$$\mathbf{d} = \mathbf{k_{TAS}} \times 0.01111 + \mathbf{E} + (1\mathbf{xRNP})$$

Paragraph 4.1. DETERMINING PRECISION FINAL APPROACH FIX/FINAL APPROACH FIX (PFAF/FAF) COORDINATE.

Formula 4.1

$$\mathbf{z} = \mathbf{A} - \mathbf{F}$$

Formula 4.2

$$\mathbf{D_{PFAF}} = 364{,}609\left[90 - \theta - sin^{-1}\left(\frac{20{,}890{,}537 \times sin(90+\theta)}{\mathbf{z} + 20{,}890{,}537}\right)\right] - \frac{\mathbf{TCH}}{tan(\theta)}$$

Paragraph 4.1.1. Determining Glidepath Altitude at a FIX.

Formula 4.3

$$ZZ = LTP + \frac{20{,}890{,}537 \times \sin(90+\theta)}{\sin\left(90 - \theta - \frac{D_Z + \frac{TCH}{\tan(\theta)}}{364{,}609}\right)} - 20{,}890{,}537$$

Paragraph 4.4.1b(1). ½ Width at DA ($\frac{1}{2}W_P$ @ DA).

Formula 4.4

$$\tfrac{1}{2}W_P\,@DA = 0.036(D_{DA} - 200) + 400$$

Paragraph 4.4.1b(2). ½ Width at any distance.

Formula 4.5

$$\tfrac{1}{2}W_P = \left(\frac{\frac{1}{2}W_P\,@DA - k}{D_{DA}}d\right) + k$$

Paragraph 4.4.1c. OCS.

Formula 4.6

$$h_{GQS} = \tan\left(\frac{2\theta}{3}\right)d$$

Paragraph 4.5.3a. Level Surface.

Formula 4.7

$$D_{250} = \frac{250 - TCH}{\tan(\theta)}$$

Paragraph 4.5.3b(1). Inner Sloping Surfaces.

STEP 1

Formula 4.8

$$°C = \frac{°F - 32}{1.8}$$

Formula 4.9

$$°F = (1.8 \times °c) + 32$$

STEP 2

Formula 4.10

$$deviation = °C - \left[15°C - \left(\frac{Airport\ Elevation}{500}\right)\right]$$

STEP 4

Formula 4.11

$$T_{NA} = \left[15°C - \left(\frac{Airport\ Elevation}{500}\right)\right] - (value\ from\ step\ 3)$$

Paragraph 4.5.3b(2). STEP 1 – Outer Sloping Surface.

STEP 1

Formula 4.12

$$S_W = \frac{102}{\theta}$$

STEP 2

Formula 4.13

$$D_C = \frac{(D_{250}S_W) - (200S_V)}{(S_W - S_V)}$$

Paragraph 4.5.3c(1). Inner OCS.

Formula 4.14

$$I_Z = \frac{D_o - D_{250}}{S_V}$$

Paragraph 4.5.3c(2). Outer OCS.

Formula 4.15

$$O_Z = \frac{\theta(D_o - 200)}{102}$$

Paragraph 4.5.3e. Adjustment of DA for Penetration of INNER SURFACE.

CASE 1

Formula 4.16

$$C_{elevation} = LTP_E + \frac{D_C - D_{250}}{S_V}$$

Formula 4.17

$$DA_{adjusted} = LTP_E + tan(\theta)\left(\left(D_O + \frac{TCH}{tan(\theta)}\right) + (p \times S_V)\right)$$

CASE 2

Formula 4.18

$$DA_{adjusted} = LTP_E + tan(\theta)\left[([h - c]S_W) + D_C + \frac{TCH}{tan(\theta)}\right]$$

Paragraph 4.5.3f. Adjustment for Penetration of OUTER SURFACE.

Formula 4.19

$$DA_{adjusted} = LTP_E + tan(\theta)\left[(pS_W) + D_O + \frac{TCH}{tan(\theta)}\right]$$

Formula 4.20

$$\text{Distance LTP to } DA_{adjusted} = \frac{DA_{adjusted} - LTP_E}{tan(\theta)} - \frac{TCH}{tan(\theta)}$$

Paragraph 5.4.1. Level OCS Length and Width.

Formula 5.1

$$D_{cd} = \frac{DA\,(above\ ABSL) - TCH}{tan(\theta)} - \frac{50}{tan(\theta)} + 1{,}822.83$$

Formula 5.2

$$D_{ab} = D_{cd} - 3038.06$$

Paragraph 5.4.2. MA Level Surface Obstacle Clearance.

Formula 5.3

$$h_{levelOCS} = DA - (ROC + Adustments)$$

Paragraph 5.6. Obstacle Clearance.

Formula 5.4

$$DA_{adjustment} = \frac{(40 \times \mathbf{p}) \times \theta}{102}$$

APPENDIX 2. CRITERIAL COMMENTS

1. **Paragraph 1.5.1**. Approach Surface Baseline (ASBL). With very few, if any exceptions, tangency to the orthometric geoid mean sea level (MSL) and tangency to the WGS-84 ellipsoid does not result in coincident lines. Therefore, measurements based on ASBL for instrument landing system/microwave landing system (ILS/MLS) may not exactly match the same measurements based on ASBL for WAAS/LAAS systems to the same runway. The differences, however, are small enough to be considered insignificant (see ICAO Obstacle Clearance Panel working paper 67, Tangent Differences between the Realization of the WGS-84 Ellipsoid and the Geoid).

2. **Paragraph 2.2.4**. Calculation of Descent Gradient**.** The point that aircraft begin descent during a turn to a new course has been discussed at length at the TERPS portion of the Aeronautical Charting Forum (ACF). The NBAA, RAA, ALPA, AOPA, DoD, etc., failed to arrive at a consensus opinion. Therefore, for purposes of this document, the worse-case scenario is assumed: Aircraft begin descent when they are established on course. Descent is not considered during the actual turn maneuver. The portion of the initial and intermediate segments available for descent varies with the amount of heading change required at the IF. If the intermediate segment is a continuation of the initial course (no heading change), then D is equal to the distance (L) between the plotted positions of the fixes involved. Where a turn is required at the IF, a portion (X) of the distance from the IAF to the IF, and from the IF to the FAF, is dedicated to turn initiation and regaining course alignment instead of descent.

3. **Paragraph 2.2.5.** Determining Turning Flight Track Radius - Assumption: Worse case predictable turn radius results from standard rate turns. The formula to calculate turn radius (R) is:

$$\mathbf{R} = \frac{\mathbf{V_{KTAS}}^2\left(1.4589\times10^{-5}\right)}{tan(\phi)}$$

where ϕ = bank angle required for standard rate turn, VKIAS= indicated airspeed in knots, and VKTAS= true airspeed in knots. The formula to convert from indicated to true airspeed is:

$$\mathbf{V_{KTAS}} = 0.02\left(\frac{\textbf{altitude}}{1{,}000}\right)\mathbf{V_{KIAS}} + \mathbf{V_{KIAS}}$$

reduces to

$$\mathbf{V_{KTAS}} = 0.00002(\text{altitude})\mathbf{V_{KIAS}} + \mathbf{V_{KIAS}}$$

The formula to calculate standard rate bank angle (ϕ) is:

$$\phi = tan^{-1}\left(0.00275\mathbf{V_{KTAS}}\right)$$

Therefore by substitution:

$$\mathbf{R} = \frac{\mathbf{V_{KTAS}}^2\left(1.4589\times10^{-5}\right)}{0.00275\mathbf{V_{KTAS}}}$$

which reduces to:

$$\mathbf{R} = \mathbf{V_{KTAS}}\times0.005305$$

4. Paragraph 2.2.7. Joining Segments of Differing RNP-Levels. The latency values (L) in table 2-2 are estimates. The FAA has not surveyed the differing equipment suites for latency values. The reaction time of 25 seconds was obtained from data obtained from past flight test scenarios. Transitions to smaller RNP-levels can require large anticipation distances and warrant consideration of establishing the final segment RNP-level at the IAF.

5. Paragraph 3.0.3a. BASIC Intermediate connection with precision final segment Figure 3-1A assumes the intermediate RNP-level is 1.0. The width is tapered to the final width over 2 NM. This is possible since the localizer should be captured by this point. If the RNP-level is 0.3, there is no taper, the intermediate segment ends at the PFAF at full width.

6. Paragraph 3.0.5b. Intermediate Segment. Implementation of LNAV/VNAV approach procedures has proven the traditional intermediate segment 318 ft/NM descent gradient limit does not support a seamless transition to a VNAV final segment. A lesser gradient is required to accommodate deceleration.

7. Paragraph 4.4.1b(1) ½ Width at DA **(** $\frac{1}{2}W_P$ @ DA **).** The width of the GQS at DA is equal to the width of the precision "W" surface at DA; therefore, the "W" surface width formula from precision criteria is used.

8. Paragraph 5.0. General. If a fix is located prior to the LTP for early turns, the fix becomes an FTP. Locate the FPCP above the FTP at an elevation that would result in a normal TCH over the actual LTP. For example: TCH=53', GPA=3.1°, FTP is 1,500' prior to LTP. The FPCP would be located 53'+tan (3.1°)×1,500'=134.24 feet above the FTP. Glidepath guidance will not be available after the FTP. The missed approach RNP will be larger than the RNP required for final approach to account for the possibility of a navigation error alert causing the missed approach initiation.

RISK ASSESSMENT/VALIDATION OF RNP

OBSTACLE CLEARANCE SURFACES

RISK ASSESSMENT/VALIDATION OF RNP OBSTACLE CLEARANCE SURFACES

1.0 INTRODUCTION.

The concept of Required Navigation Performance (RNP) is a significant enhancement to navigable airspace design, use, and management. It was developed by the International Civil Aviation Organization (ICAO) Special Committee on Future Air Navigation Systems (FANS) and is an integral part of the communication, navigation, surveillance, and air traffic management (CNS/ATM) plan envisioned by the Special Committee. RNP levels address obstacle protection associated with RNP accuracy values. The RNP level (RNP x, where x=0.3, 1, 2, etc.), when applied to instrument procedure obstacle evaluation areas, is a variable used to determine a segment primary area half-width value; i.e., total width is ± a multiple of the value used to identify the level. Order 8260.51, a proposed Advisory Circular (AC) 90-series, and a proposed AC 20-series, will provide the requirements to ensure safe operations on RNP procedures.

The RNP level is based on the total system error (TSE) allowed in the horizontal dimension--lateral and longitudinal (cross-track and along-track). For the lateral dimension, the TSE is assumed to be the difference between the true position of the aircraft and the centerline of the route of flight programmed in the NAV system. The TSE is a combination of the navigation system error (which includes area navigation (RNAV) computation error and display system error as well as navigation signal discrepancies) and the flight technical error (FTE). A single accuracy value expresses RNP types in nautical miles. For example, for RNP-1, the TSE is not to exceed 1.0 NM for 95 percent of the flight time on any portion of any single flight. RNP can apply from takeoff to landing with each phase of flight requiring a different RNP type.

At this time, there are no regulations defining requirements for RNP systems operating in the U.S. National Airspace System (NAS). ICAO has formalized certain standards in ICAO Doc 9613-AN/397, "Manual on Required Navigation Performance (RNP)". RTCA, a private industry-government supported federal advisory committee, has published a Minimum Aviation System Performance Standards (MASPS) for RNP systems (and has even updated it once) DO-236A. But there are no binding definitions as to what is and what isn't an RNP airplane in the NAS. This paper assumes certain basic capabilities are inherently part of Required Navigation Performance based systems.

1. The navigation system is capable of locating the aircraft within 1 RNP of its true position 95.0% of the time. (This requirement drives infrastructure requirements in most cases as well as database requirements - see item 6.)

2. Integrity of the positioning accuracy is better than 99.999% per flight hour at 2 x RNP as is integrity against misleading navigation information.

3. Continuity of the required position accuracy is better than 99.99%.

4. The service is available at the required levels more than 99.999% of the time.

5. There is some means for the pilot to monitor the navigation system performance of the aircraft. (This information may be on a secondary screen on the FMS but it must

be accessible. The optimal system would combine the NAV performance with the current Flight Technical Error (FTE) and display the information in the pilot's primary visual field. But in most cases there must be additional training or information available to the pilot for guidance in combining the navigation system performance information with the current FTE situation so that the pilot can evaluate the RNP status.)

6. Database standards and processes are in place to ensure that position information on fixes, runways, etc., does not compromise the navigation capabilities of the RNP system.

The risk evaluations presented in section 2 of this paper assume the system is available and that any continuity problems during the operation are not of significant duration. It further assumes that all combinations of misinformation (integrity, database issues, and navigation service performance) are sufficiently small that they do not cause the system to exceed the containment requirements.

RNAV is the primary means of meeting RNP requirements. RNAV operations, within the RNP concept, permit flight in any airspace within prescribed accuracy tolerances without the need to fly directly over ground-based navigation facilities. Any type of navigation system can be used to provide RNP, provided that it meets the required navigation performance requirements. RNAV equipment operates by automatically determining the aircraft position using inputs from one source, or a combination of sources such as DME, INS, and GPS (with or without augmentation). The primary means for achieving RNP is by the use of RNAV equipment.

RNP extends the capabilities of modern airplane navigation systems by providing real-time estimates of navigation uncertainty, assurance of performance through its containment concepts, and features that ensure the repeatability and predictability of airplane navigation. This precise characterization of airplane performance is key to designing more efficient airspace routes and procedures.

Current RNP system requirements were developed to ensure consistency of flight paths and operations across the fleet. For example, the types of flight plan legs that could make up RNP route segments were limited and standardized to ensure that all similarly equipped airplanes fly consistent and repeatable paths over the ground for a given airway or procedure. The system also must have available a real-time display of the estimated navigation system accuracy. With an explicit display of the estimated accuracy, the flight crew can monitor trends while the navigation system automatically checks current performance against required performance (i.e., the RNP necessary for the operation). Full RNP systems provide alerts to the flight crew when performance is inadequate for the current operation. Lesser systems may require the crew to monitor the estimated position of uncertainty (EPU) or actual navigation performance (ANP) and determine when that value, combined with the FTE the crew is capable of maintaining, is no longer safe.

This report will provide supporting material justifying values used for determining obstacle clearance zones for certain RNP operations defined in Order 8260.51, including straight, level flight; fly-by turns between two legs of the same RNP; and straight flight through a transition from a higher RNP to a lower one. The supporting arguments assume that the certification process ensures that the systems do meet the RNP requirements.

Familiarity with the figures and text in the order is assumed and some references are implied rather than explicitly stated.

2.0 RNP CONTAINMENT ANALYSES.

The analyses cover the basic segment construction and joining guidance contained in the subject order that is employed to construct an RNP approach procedure. They assume navigation service availability and that continuity and integrity problems are not significant enough to affect containment.

2.1 Straight and Level Flight.

Paragraph 2.2.1 of subject order defines the segment width of the RNP primary and secondary/transition surfaces. A common interpretation of the 95 percent containment requirement for RNP assumes that the aircraft must be within 1 x RNP of the desired lateral position (intended flight track) at least 95 percent of the time for the entire flight. Assuming a Gaussian distribution of the TSE, the 95 percent requirement would support 99.991% lateral containment at 2 x RNP and 99.9999996% at 3 x RNP. Most RNP definitions, however, imply that the containment includes longitudinal (along-track) variations as well, so that the 95% containment is in a circular or at least elliptical plane parallel to the ground. This interpretation is complicated by the fact that the longitudinal errors do not include flight technical error (at least, not in the traditional way). But to maintain 95% total containment, the lateral containment must be greater than 95% and the resultant risk of exceeding the 2 or 3 x RNP distances from centerline reduced. If the extreme case of zero FTE is examined, so that the distribution is circular, the lateral containment at 1 x RNP is 98.6%; at 2 x RNP, it is 99.9999%; and at 3 x RNP, it is greater than 99.99999999% (ten 9's) (again assuming Gaussian). In either case, the 3 x RNP surface appears to significantly exceed the 10-7 protection levels provided by conventional systems if the assumption of Gaussian TSE is correct.

Historically, aviation TSE data has been shown to be non-Gaussian with a tendency toward thicker tails, meaning a higher probability of being outside a given boundary. Quantification of just how much higher is a non-trivial process requiring test data that does not yet exist for most RNP type systems. On the other hand, the ability to monitor the current navigation system performance and/or receive an alarm if the TSE approaches an unacceptable level should provide a significant mitigation that will be increasingly important as more RNP systems become available and familiarity with system operation increases.

For Special Aircraft and Aircrew Authorization Required (SAAAR) operations, the 2 x RNP surface does not of itself provide adequate obstacle protection. Depending on the requirements applied and even if the Gaussian assumption is supported, the 2 x RNP surface is either a 99.99% or a 99.9999% surface, both short of conventional safety standards. To compensate for this, additional crew training and/or aircraft equipage is required to obtain the special authorization. This may take the form of training to minimize FTE, setting tighter alarm limits than normal, or other methods that the certifying authority feels provides the additional safety margins to achieve equivalency.

2.2 Fly-by Turns Between Segments With Equal RNP Levels.

Paragraph 2.2.6 of subject order addresses the construction of obstacle protection areas for aircraft executing fly-by turns over a junction connecting two segments with equal RNP requirements. Proper execution of a fly-by turn involves initiating the turn sufficiently in advance of the turn waypoint that when the turn is completed, the aircraft will roll out on the outbound course with little or no overshoot. The lead distance (or turn anticipation distance) at which the turn must be initiated is determined by the angle of the turn, the speed of the aircraft, and the bank angle used. A less important but still significant factor in the turn anticipation calculation is the roll rate which the aircraft uses to achieve that bank angle. Notification to the pilot of arrival at the turn anticipation point is provided by visual and/or audible signals that vary from system to system. Guidance around part or all of the turn is usually available. Normal execution of this maneuver will take the flight track inside the turn waypoint. For large angle turns at high speed, the distance inside can be substantial. Subsequently, the inner boundary must be expanded to accommodate this effect.

The outer boundaries, which are constructed with 2 x RNP and 3 x RNP arcs connecting tangent points on the two segment boundaries, provide protection equivalent to the straight segment for aircraft that fly right up to the turn waypoint and then turn (such as helicopters). There is no apparent extra protection for aircraft that overshoot the outbound course.

The inner boundaries are determined by calculating a radius of turn, ***r***, (based on the factors discussed above) and constructing arcs of radius ***r*** and ***r*** + 1 x RNP to connect the inner 3 x RNP and 2 x RNP boundaries, respectively. This produces an increased obstacle clearance area on the inside of the turn, i.e. more than 2 x RNP in the primary and more than 3 x RNP in the secondary. This, in turn, allows additional protection for early turns and compensates for the lack of consideration of roll-in and rollout on the turns. The more severe the turn, the greater is the additional protection.

While protection areas appear to generally provide the same or greater protection than the straight course, the absence of any apparent overshoot provisions may require a higher level of complexity in RNP navigation systems. They must provide compensation for acceleration and strong tail-wind components, both of which tend to produce overshoots on turns. The additional inside protection should provide adequate protection for deceleration and head-winds. Additional checks on the capabilities of various systems turn algorithms should be considered to ensure a minimal probability of producing overshoots.

The last point is especially significant with regards to SAAAR systems, which do not have a secondary/transition area to provide climb out protection if the RNP level is exceeded while in a turn. However, SAAAR operations may include RF segment capabilities that would provide a fixed course to fly around turns and would substantially mitigate this problem.

2.3 Straight Flight from a Greater to a Lesser RNP Level.

RNP systems perform an immediate transition when passing from a segment of larger RNP value to one of smaller RNP. A common situation would be the transition from an RNP 1.0 segment to an RNP 0.3 segment on an approach. In this case, an aircraft that was a mile off centerline in the higher RNP segment due to a combination of flight technical error and navigation system error would find itself outside the normal straight segment protected airspace which only extends to 3 x RNP or 0.9 NM from centerline. To protect the aircraft in this situation, paragraph 2.2.7 defines a fix distance derived from an equipment latency time, a pilot reaction time, and a climb distance for a 40:1 gradient to clear the relevant obstacle. The fix distance should allow the pilot to be alerted to the possibility of being outside protected airspace, react to the alert, and climb to a sufficient altitude to clear the obstacle. If the distance is not adequate to allow this escape maneuver, then the fix must be backed up farther from the critical obstacle.

Calculation of the climb distance is straightforward and explained in the order and by Equation 2.5 in the order. Derivation of the distance due to the latency and reaction times is equally simple based on the maximum speeds appropriate for the category of aircraft that may be performing the operation.

Unfortunately, no equipment latency time is defined for RNP systems. In fact, some systems that will likely be approved for these operations do not give an alert; therefore, pilot monitoring of the estimated navigation performance and awareness of the current FTE must accomplish this function. The latency time of 10 seconds included in the order is intended to represent a conservative estimate based on experiences with a wide range of navigation systems.

Pilot reaction time data exists from a multitude of test programs, but the variability in alerting methods (or lack thereof) in RNP systems makes selecting a single data set difficult. “Untrained” times in the range of 20 to 25 seconds have been observed in pilot responses to air traffic controller directions. Response times to TCAS alerts have been measured in the 15 to 18 second range. A response time allowance of 25 seconds should represent a conservative value that can be reduced if significant experience with the system shows the reduction to be appropriate.

2.4 Additional Analyses.

As new operations or transitions are defined or clarifications requested, additional paragraphs may be added to this document.

3.0 CONCLUSIONS.

RNP operations as defined in the Order 8260.51 appear to maintain acceptable risk levels in terms of containment provided the certification process ensures compliance with defined RNP requirements. SAAAR operations must be examined carefully to ensure that training or equipage offered as mitigations to decreased containment margins is sufficient compensation for the two or three orders of magnitude increase in containment risk.

The apparent absence of overshoot protection in the fly-by turn dictates that special care also be exercised in consideration of turn algorithms and turn anticipation determination logic. This is particularly true for the SAAAR operations that do not include the secondary/ transition zone.

U.S. Department
of Transportation

**Federal Aviation
Administration**

Directive Feedback Information

Please submit any written comments or recommendations for improving this directive, or suggest new items or subjects to be added to it. Also, if you find an error, please tell us about it.

Subject: Order 8260.51, United States Standard for Required Navigation Performance (RNP) Instrument Approach Procedure Construction

To: DOT/FAA
Flight Procedure Standards Branch, AFS-420
P.O. Box 25082
Oklahoma City, OK 73125

(Please check all appropriate line items)

☐ An error (procedural or typographical) has been noted in paragraph _______ on page ______.

☐ Recommend paragraph ______ on page ______ be changed as follows:
(*attach separate sheet if necessary*)

☐ In a future change to this directive, please include coverage on the following subject:
(*briefly describe what you want added*):

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: ______________________________ Date: __________________

FTS Telephone Number: _________________________________ Routing Symbol: ________